

SSME ALTERNATE TURBOPUMP DEVELOPMENT PROGRAM (HPOTP)

**VERIFICATION COMPLETE REPORT
FIRST TURBINE VANE AERODYNAMIC DESIGN
DVS DR NO. 3.1.2.2.5.1, VM NO. 4.1.2.4 A**

JUNE 1989

**Prepared under
NASA Contract NAS8-36801
DRL Sequence No. SE12
WBS No. 1.5.1.2**

**Prepared for
George C. Marshall Space Flight Center
National Aeronautics and Space Administration
Marshall Space Flight Center, AL 35812**

**Prepared by
Pratt & Whitney
P. O. Box 109600
West Palm Beach, FL 33410-9600**



**UNITED
TECHNOLOGIES
PRATT&WHITNEY**

SSME ALTERNATE TURBOPUMP DEVELOPMENT PROGRAM (HPOTP)

**VERIFICATION COMPLETE REPORT
FIRST TURBINE VANE AERODYNAMIC DESIGN
DVS DR NO. 3.1.2.2.5.1, VM NO. 4.1.2.4 A**

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Approved by:

John W. Price Jr.
W. C. Shubert
ATD Project Manager

(NASA-CR-183759) SSME ALTERNATE TURBOPUMP
DEVELOPMENT PROGRAM (HPOTP). VERIFICATION
COMPLETE REPORT: FIRST TURBINE VANE
AERODYNAMIC DESIGN DVS DR NO. 3.1.2.2.5.1,
VM NO. 4.1.2.4 A (PWA) 34 p

N90-70028

00/20 0233349
Unclassified



HPOTP Turbine Aerodynamic Design

The High Pressure Oxidizer Turbopump (HPOTP) turbine aerodynamic design is based on the requirements defined by the Interface Control Document (ICD) and by the Power Balance Model, Table 387B. Performance Table 387B was used for the turbine aerodynamic design because its turbine flow capacities are consistent with the baseline turbine nozzle flow test results conducted on Pratt & Whitney's test stand, E-6, in December, 1986.

A 3-stage turbine was selected over a 2-stage design for three basic reasons:

1. To retain desired efficiency at the reduced pump speeds.
2. To provide adequate performance margin with unshrouded blades.
3. To ensure adequate margins for adjusting to cycle requirements.

A conventional pressure-compounded, 3-stage design was chosen because of its inherent high efficiency with low aerodynamic risk. This aerodynamic advantage allowed the use of unshrouded blades. Unshrouded blades are desirable because they permit the use of PW1480 single-crystal material, which provides superior thermal fatigue characteristics, but at the present state-of-the-art, cannot be easily cast in the form of shrouded blades in this small size. The turbine aerodynamic design provides relatively high velocity ratios, which are within the range of normal design practice and experience. Avoiding lower velocity ratios eliminates excessive gas turning, and the need for blades with excessively small leading edge radii. Blades with sharp leading edges make the turbine intolerant at incidence angle changes resulting from off-design operation. Under such conditions, severe flow separation is common.

The methodology associated with the design of the HPOTP starts with the meanline design analysis. This analysis is based on the assumption that the flow through the turbine can be represented by the flow at the center of the flow passage. This simplified approach permits selection of the number of stages required, the mean diameter of the flow passage, and the annulus area. Included in the analysis is an estimate of the aerodynamic efficiency. This prediction system uses the physical laws of aerodynamics and correlations from rig and engine data to estimate profile loss, secondary loss, blade tip leakage, and shock and incidence losses based on the geometry and aerodynamic parameters of the turbine. An interactive graphic flowpath design system is used, in conjunction with the optimum meanline design, to generate candidate flowpath configurations.

The streamline design analysis is used to optimize the radial variation in the velocity triangles, once the average conditions are selected from the meanline analysis. This analysis calculates the flow characteristics at numerous radial locations and at the inlet and exit of each airfoil row. Once the meanline and streamline analyses have been used to optimize the velocity triangles throughout the turbine, 2 dimensional (2-D) airfoil sections are designed. These airfoil sections are designed to achieve contours that provide the desired amount of flow turning without permitting the flow to separate from

the airfoil surface. This process involves determining the static pressure distributions and boundary layer parameters along the airfoil surfaces and endwalls. An interactive graphics airfoil design system is used to identify adverse static pressure gradients such that the airfoil contour can be modified appropriately. After the 2-D airfoils are estimated at several spanwise locations, they are radially faired and combined with a preliminary endwall definition. An inviscid multi-stage 3-D flow analysis is then used to refine and optimize the entire flowpath configuration.

All turbine airfoil, endwall, inlet, and exit flow passage surfaces are contoured and refined as a system. The multi-stage feature enables a complete evaluation of potential changes to an individual surface contour during the design process. This assessment includes, not only flow property changes around the component being modified, but also around all upstream and downstream components in the complete turbine system. Improved performance and reduced risk result from this global optimization capability.

This report contains:

- o Hot elevation diagrams for each airfoil
- o 3-D airfoil plots
- o 2-D airfoil section plots
- o Tabulated airfoil section coordinates
- o A plot of hot gaging dimensions versus radius
- o A plot of percent change in flow area versus airfoil rotation
- o A plot of stress versus span
- o 3-D airfoil static pressure distributions
- o Airfoil Ps/PT and Mach number contours
- o A plot of suction surface boundary layer friction coefficient versus surface distance

COVER SHEET

SPACE SHUTTLE

ENGINE A.T.D. Oxidizer Pump Turbine

AIRFOIL 1st Vane

ENGINEER Branstrom EXT 2824 DATE

AERODYNAMIC DESIGN POINT 109% Power - Des. Table 0387.8 Dated 4/10/87

F.T.D. LIST:

ELEVATION _____

AIRFOIL SECTIONS N.A.

AIRFOIL COORDINATES N.A.

DF LIST:

GAGING VS. RADIUS N.A.

FLOW AREA VS. ROTATION N.A.

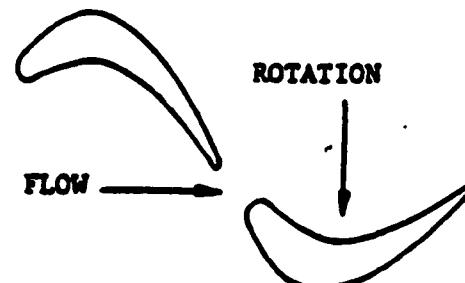
STRESS VS. % SPAN N.A.

PRESSURE DIST. N.A.

BOUNDARY LAYER N.A.

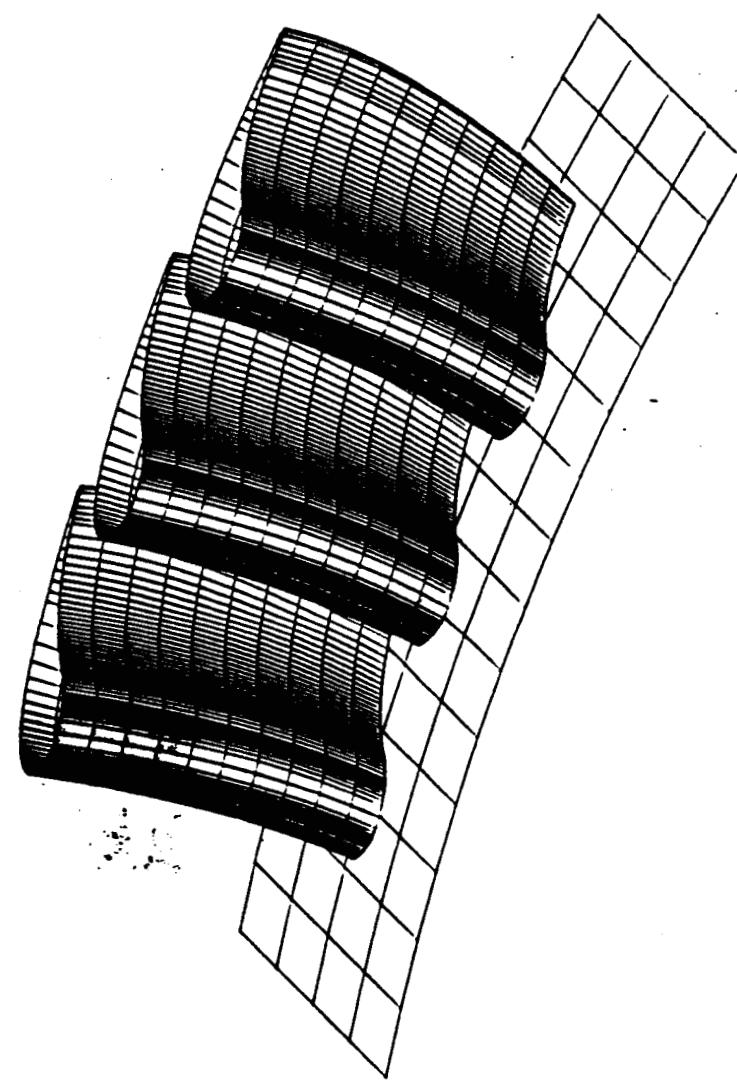
P&WA COUNTER ROTATION

VANE ✓ BLADE _____



VIEW LOOKING RADIALLY INWARD

3D PLOT



ATC 104 1V

b-1

25 . 44 15 . 89 02 / 0 / 8808 . 44 . 11
45 . 44

CYL NORMICAL
SCALE 10.0
THERMAL SHRINK FACTOR 1.00000
17/18/87
17:28:34

NUMBER OF BLADES 82
RADIUS (HOT) 5.247 INCHES
DAGING (HOT) 0.0988 INCHES
PITCH (HOT) 0.1020 INCHES
AXIAL WIDTH 0.1060 INCHES
BLADE INLET ANGLE 90.000 DEGREES
DAS INLET PBLE 0 DEGREES
BLADE EXIT ANGLE 54.360 DEGREES
DAS EXIT ANGLE 0 DEGREES
DAGING ANGLE 14.230 DEGREES
UNCOVERED TURNING 20.705 DEGREES
LEADING EDGE RADIUS 0.0350 INCHES
TRAILING Edge RADIUS 0.0100 INCHES
TOTAL AREA (SOLID) 0.66850 IN.
METAL AREA
(NET, UNCOATED) 0.049750 IN.

X C.S. 0.0129 0.0000
+ STATION LINE 0.0000 0.0000
GRATE 0.1188 0.0000

ATQ LOK 14

TANGENTIAL COORDINATE

-0.40 -0.30 -0.20 -0.10 0.00 0.10 0.20 0.30 0.40 0.50 0.60 0.70 0.80

AXIAL COORDINATE

-0.20 -0.10 0.00 0.10 0.20

CYLINDRICAL
SCALE 10.0
THERMAL SHINK FACTOR 1.00000

17:28:34

NUMBER OF BLADES

JOURNAL OF CLIMATE

INCOME STATEMENT

EXCELSIOR MURKIN

BLNOE INLET ANGLE 90 DEGREE

DEGREE

SUPPLEMENTAL INFORMATION

ESTATE PLANNING

UNCOVERED TURN 1 103 21.525 DEGREE

ENDING EDGE RADIUS D. Ø353 INCHES

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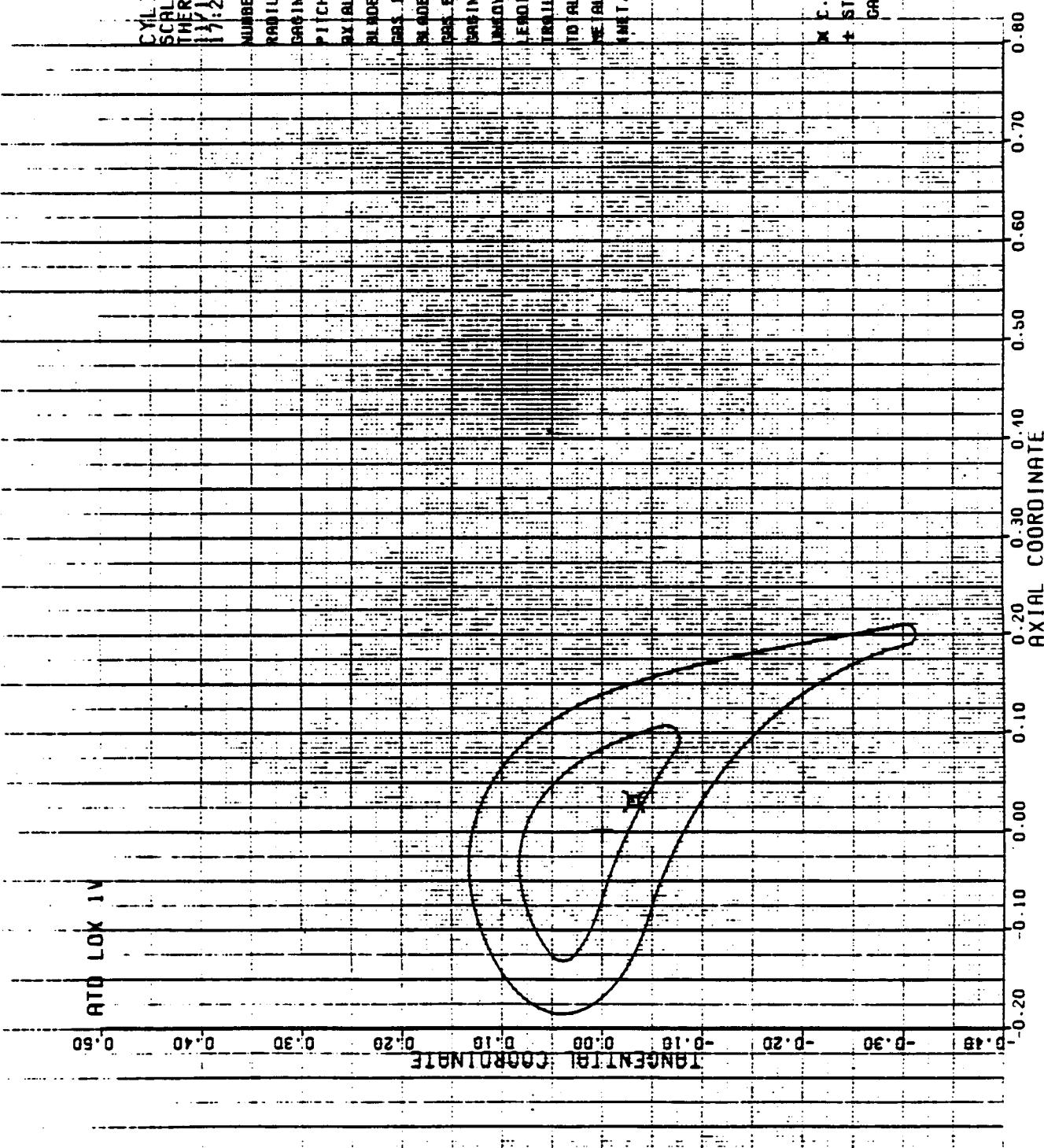
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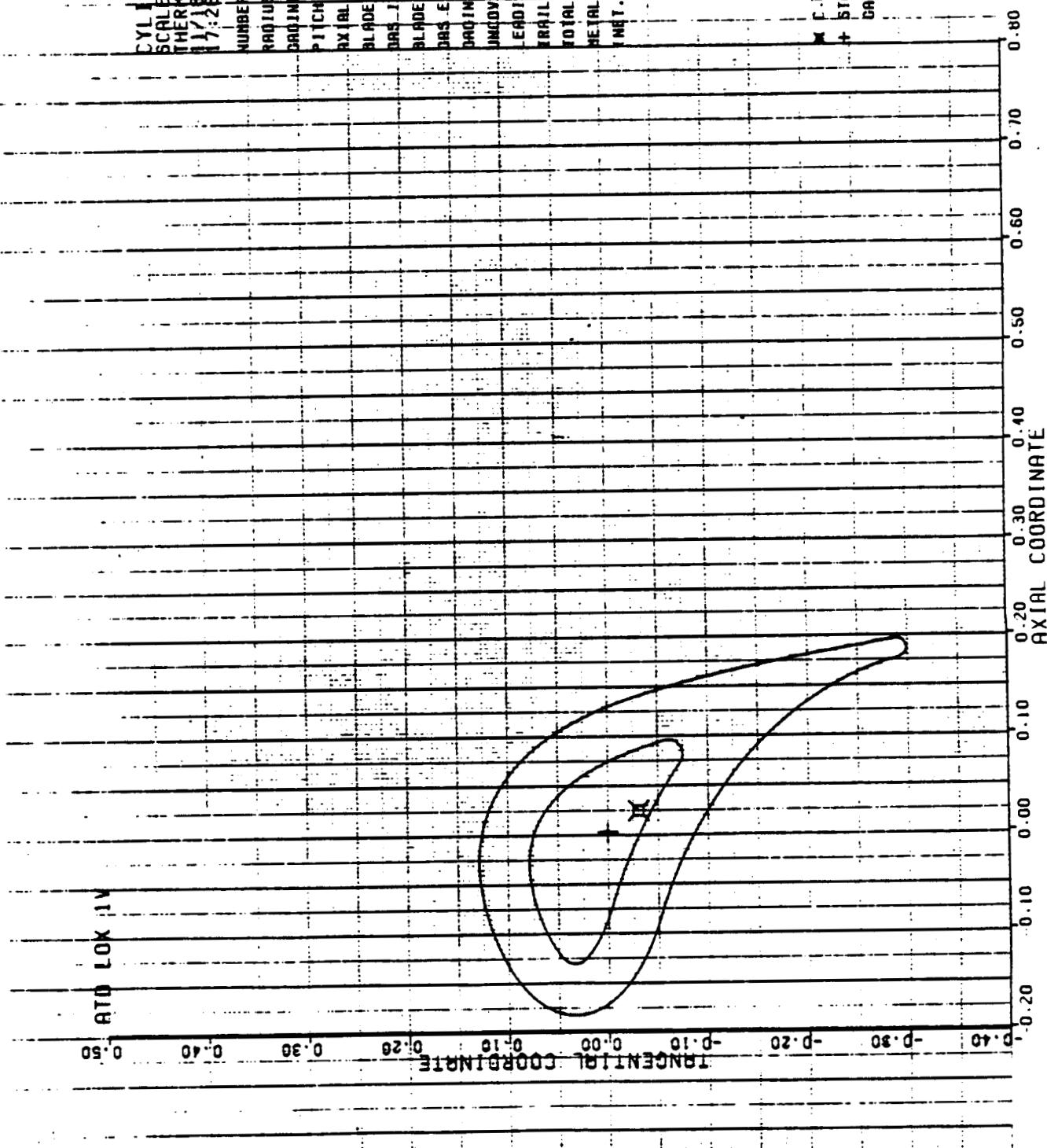
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CYLINDER CAL
SCALE 10.0
THERMAL SHRINK FACTOR 1.000000

NUMBER OF BLADES	RADIUS (HOT)	RADIUS (COLD)	PITCH (HOT)	PITCH (COLD)	BLADE INLET ANGLE	DAS INLET ANGLE	BLADE EXIT ANGLE	DAS EXIT ANGLE	DASDING ANGLE	UNCOVERED FURNACE	EATING EDGE RADIUS	TRAILING EDGE RADIUS	TOTAL AREA (SOLID)	MATERIAL AREA
82	1.973	1.000	0.0813	0.0813	0.3811	0.3811	0.3810	0.3810	0.0000	0.0000	0.0000	0.0000	0.0665	0.0473
83	8.443	8.443	0.404	0.404	0.2148	0.0367	0.0101	0.0101	0.0000	0.0000	0.0000	0.0000	50	50
84	1.973	1.000	0.0813	0.0813	0.3811	0.3811	0.3810	0.3810	0.0000	0.0000	0.0000	0.0000	0.0665	0.0473



CYLINDRICAL
SCALE 10.0
THERMAL SHRINK FACTOR 1.00000

17.13:87

17.23:84

NUMBER OF BLADES	82	INCHES
RADIUS (HOT)	4.137	INCHES
GAGING (HOT)	0.3845	INCHES
PITCH (HOT)	0.1705	INCHES
AXIAL WIDTH	0.3680	INCHES
BLADE INLET ANGLE	90.033	DEGREES
BLADE INLET RADIUS	0.000	INCHES
BLADE EXIT ANGLE	35.161	DEGREES
BLADE EXIT RADIUS	0.000	INCHES
GAGING ANGLE	13.197	DEGREES
UNIVERSAL TURNING	2.1130	DEGREES
LEADING EDGE RADIUS	0.0361	INCHES
TRAILING EDGE RADIUS	0.0102	INCHES
TOTAL AREA (SOLID)	0.1615	SQ. IN.
PER BLADE	0.0019	SQ. IN.
(NET, UNCORRECTED)		

C.G.
 STACKING LINE
 GATE

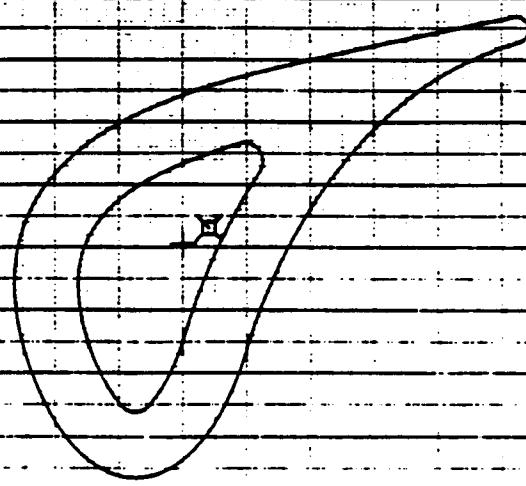
ATD Lox 1V

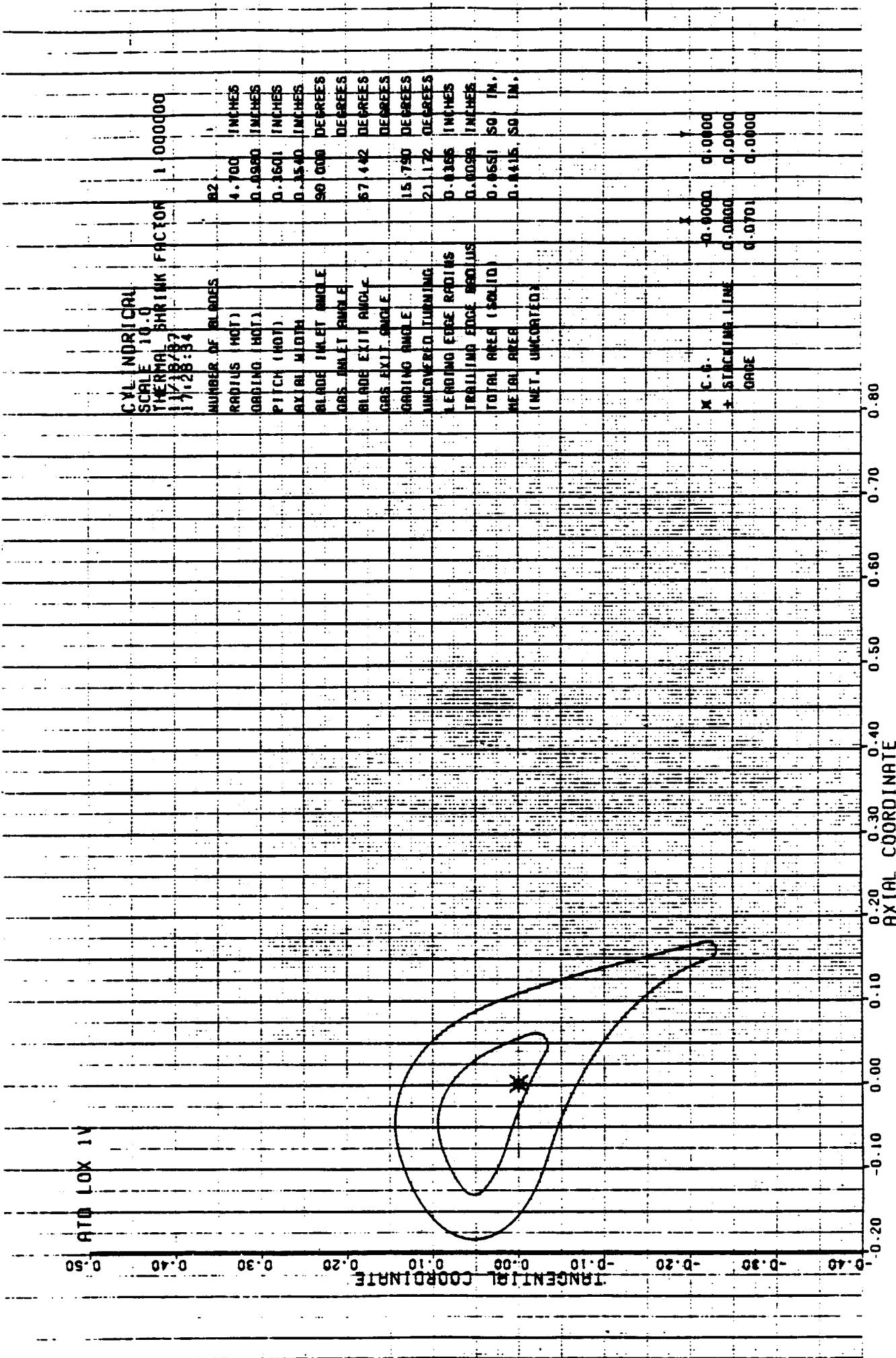
-0.40 -0.30 -0.20 -0.10 0.00 0.10 0.20 0.30 0.40 0.50

TRANSIENT COORDINATE

0.20 0.30 0.40 0.50 0.60 0.70 0.80

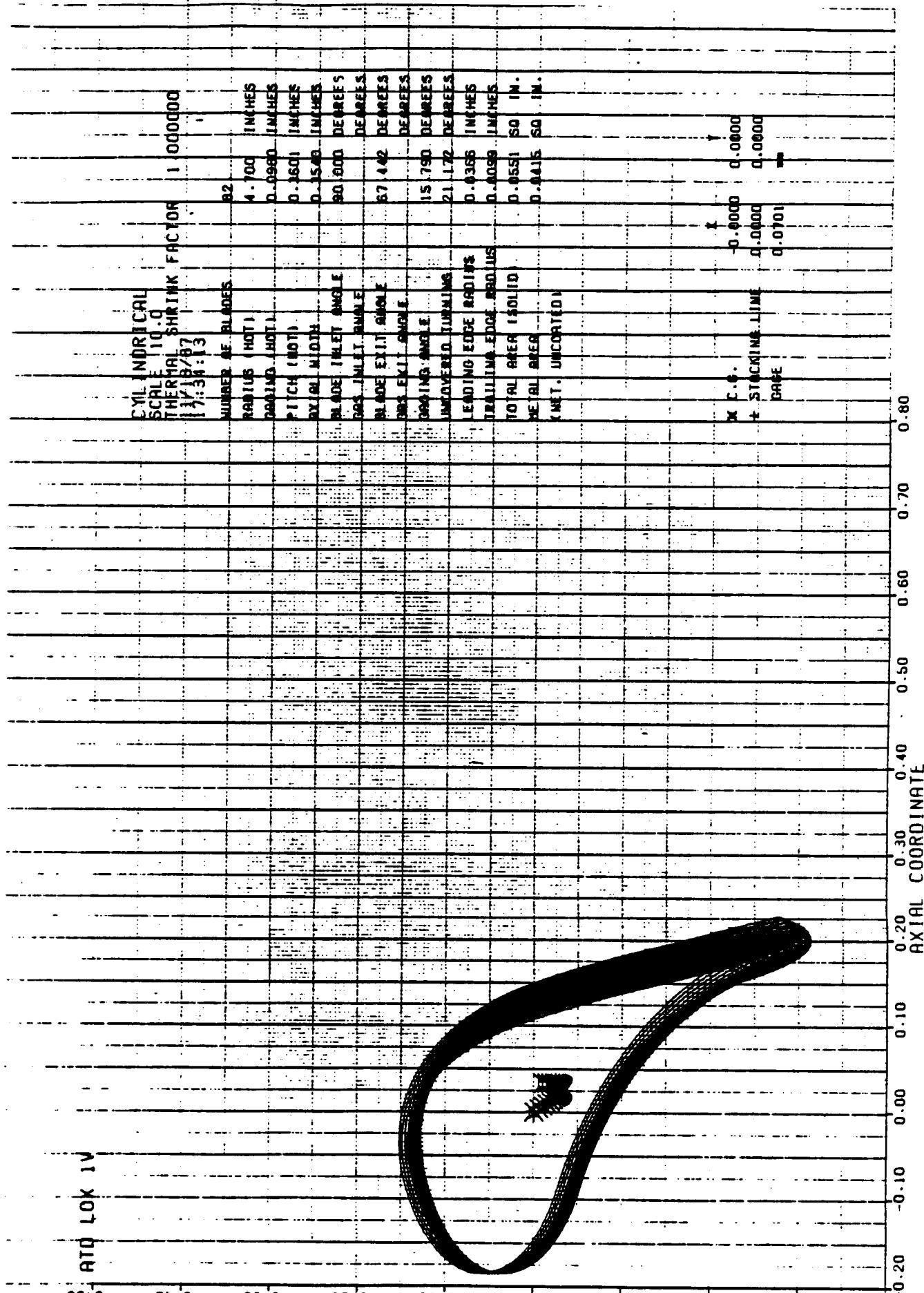
AXIAL COORDINATE





ATQ LOK IV

-0.40 -0.30 -0.20 -0.10 0.00 0.10 0.20 0.30 0.40 0.50
TANGENTIAL COORDINATE



0.20 0.30 0.40 0.50 0.60 0.70 0.80
AXIAL COORDINATE

EXTERNAL 'SOUR
TD 0 TD REV. 0 PART NO. TITLE - ATD LDX 1V
SUBTITLE

DATE 11/18/87 TIME 17:28:14
COLD RADIUS = 0.0 THERMAL SHRINK FACTOR = 1.000000

PRETEXT NOT USED FOR TD PRINTOUT.

PCT X	X TOP	Y TOP	(CIRCLE)	X BOT	Y BOT	(CIRCLE)
0.0	-0.18567	0.05522	0.05222	-0.18567	0.04922	0.05222
0.010	-0.16213	0.07096		-0.16213	0.03369	
0.020	-0.17859	0.07860		-0.17859	0.02585	
0.030	-0.17505	0.08438		-0.17505	0.02007	
0.040	-0.17151	0.08918		-0.17151	0.01527	
0.050	-0.16797	0.09335		-0.16797	0.01109	
0.060	-0.16443	0.09707		-0.16443	0.00738	
0.070	-0.16089	0.10044		-0.16089	0.00401	
0.080	-0.15735	0.10352		-0.15735	0.00092	
0.090	-0.15381	0.10637		-0.15381	-0.00193	
0.100	-0.15027	0.10903		-0.15027	-0.00458	
0.125	-0.14142	0.11496		-0.14142	-0.01051	
0.150	-0.13257	0.12008		-0.13257	-0.01564	
0.175	-0.12372	0.12458		-0.12372	-0.02013	
0.200	-0.11487	0.12856		-0.11487	-0.02411	
0.225	-0.10602	0.13209		-0.10602	-0.02765	
0.250	-0.09717	0.13524		-0.09717	-0.03179	
0.275	-0.08832	0.13805		-0.08832	-0.03560	
0.300	-0.07947	0.14042		-0.07947	-0.03629	
0.325	-0.07062	0.14221		-0.07062	-0.03915	
0.350	-0.06177	0.14363		-0.06177	-0.04210	
0.375	-0.05292	0.14406		-0.05292	-0.04538	
0.400	-0.04407	0.14410		-0.04407	-0.04677	
0.425	-0.03522	0.14355		-0.03522	-0.05236	
0.450	-0.02637	0.14239		-0.02637	-0.05114	
0.475	-0.01752	0.14061		-0.01752	-0.04615	
0.500	-0.00867	0.13816		-0.00867	-0.04317	
0.525	0.00018	0.13503		0.00018	-0.04094	
0.550	0.009203	0.13118		0.009203	-0.03726	
0.575	0.01788	0.12654		0.01788	-0.03564	
0.600	0.02673	0.12105		0.02673	-0.03392	
0.625	0.03558	0.11463		0.03558	-0.03942	
0.650	0.04443	0.10715		0.04443	-0.03216	
0.675	0.05328	0.09848		0.05328	-0.01617	
0.700	0.06213	0.08939		0.06213	-0.00491	
0.725	0.07098	0.07659		0.07098	-0.11561	
0.750	0.07983	0.06260		0.07983	-0.1234	
0.775	0.08868	0.04593		0.08868	-0.13168	
0.800	0.09753	0.02306		0.09753	-0.14074	
0.825	0.10638	0.00308		0.10638	-0.15067	
0.850	0.11523	-0.02306		0.11523	-0.16167	
0.875	0.12408	-0.05185		0.12408	-0.17008	
0.900	0.13293	-0.08277		0.13293	-0.1843	
0.910	0.13647	-0.09562		0.13647	-0.19493	
0.920	0.14001	-0.10870		0.14001	-0.2001	
0.930	0.14355	-0.12198		0.14355	-0.2083	
0.940	0.14709	-0.13545		0.14709	-0.21667	
0.950	0.15063	-0.14909		0.15063	-0.2276	
0.960	0.15417	-0.16287		0.15417	-0.22949	
0.970	0.15771	-0.17679		0.15771	-0.23318	
0.980	0.16125	-0.19082		0.16125	-0.2296	
0.990	0.16479	-0.20495		0.16479	-0.2203	-0.22790
1.000	0.16833	-0.21909		0.16833	-0.22610	-0.22031

NO. 1 COR. JANTOUR TD 0 TO REV. O PART NO. END NO.
SUBTITLE HOT RADIUS = 4.700000 COLD RADIUS = 0.0 THERMAL SHRINK FACTOR = 1.000000

TITLE - A10 LOX IV DATE 11/16/87 TIME 17:26:14
CYLINDRICAL PRETRUST NOT USED FOR TD PRINTOUT.

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0.020	-0.12876	0.06279	0.06239	-0.12876	0.04203	0.04230
0.030	-0.12683	0.06420	0.06419	-0.12683	0.04050	
0.040	-0.12490	0.06560		-0.12490	0.03899	
0.050	-0.12297	0.06700		-0.12297	0.03750	
0.060	-0.12104	0.06837		-0.12104	0.03607	
0.070	-0.11911	0.06971		-0.11911	0.03470	L.E. CIRCLE (X,Y,R)
0.080	-0.11718	0.07100		-0.11718	0.03312	T.E. CIRCLE (X,Y,R)
0.090	-0.11525	0.07225		-0.11525	0.03213	
0.100	-0.11332	0.07344		-0.11332	0.03093	L.E. TOP TANG. PT. (X,Y)
0.125	-0.10850	0.07623		-0.10850	0.02816	L.E. BOTTOM TANG. PT. (X,Y)
0.150	-0.10358	0.07825		-0.10358	0.02562	T.E. TOP TANG. PT. (X,Y)
0.175	-0.09865	0.08102		-0.09865	0.02345	T.E. BOTTOM TANG. PT. (X,Y)
0.200	-0.09403	0.08308		-0.09403	0.02138	
0.225	-0.08921	0.08499		-0.08921	0.01946	NOSE POINT (X,Y)
0.250	-0.08438	0.08679		-0.08438	0.01768	TAIL POINT (X,Y)
0.275	-0.07956	0.08845		-0.07956	0.01605	
0.300	-0.07473	0.08996		-0.07473	0.01453	
0.325	-0.06991	0.09128		-0.06991	0.01306	
0.350	-0.06509	0.09227		-0.06509	0.01160	
0.375	-0.06026	0.09322		-0.06026	0.01009	
0.400	-0.05544	0.09381		-0.05544	0.00851	
0.425	-0.05062	0.09412		-0.05062	0.00689	
0.450	-0.04579	0.09414		-0.04579	0.00521	
0.475	-0.04097	0.09387		-0.04097	0.00349	
0.500	-0.03615	0.09331		-0.03615	0.00172	
0.525	-0.03132	0.09246		-0.03132	0.00010	
0.550	-0.02650	0.09110		-0.02650	0.00126	
0.575	-0.02167	0.08981		-0.02167	0.00368	
0.600	-0.01685	0.08799		-0.01685	0.00585	
0.625	-0.01203	0.08582		-0.01203	0.00787	
0.650	-0.00720	0.08329		-0.00720	0.00995	
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0.700	0.00244	0.07702		0.00244	0.01429	
0.725	0.00727	0.07323		0.00727	0.01655	
0.750	0.01209	0.06996		0.01209	0.01887	
0.800	0.02174	0.05777		0.02174	0.02125	
0.825	0.02556	0.05450		0.02556	0.02621	
0.850	0.03139	0.04590		0.03139	0.02879	
0.875	0.03621	0.03817		0.03621	0.03145	
0.900	0.04103	0.02938		0.04103	0.03417	-0.03373
0.910	0.04296	0.02555		0.04296	0.03529	-0.03416
0.920	0.04489	0.02154		0.04489	0.03641	-0.03434
0.930	0.04682	0.01734		0.04682	0.03755	-0.03427
0.940	0.04875	0.01296		0.04875	0.03870	-0.03394
0.950	0.05068	0.00841		0.05068	0.03986	-0.03335
0.960	0.05261	0.00371		0.05261	0.04104	-0.03245
0.970	0.05454	-0.00116		0.05454	-0.04223	-0.03117
0.980	0.05647	-0.00618		0.05647	-0.04343	-0.02937
0.990	0.05840	-0.01136		0.05840	-0.04460	-0.02668
1.000	0.06033	-0.01670	-0.01931	0.06033	-0.04588	-0.01931

EXTERNAL L...FOUR
TD 0 TD REV. 0 PART NO.
SUBTITLE

TITLE - ATD LOX IV
END NO.
COLD RADIUS = 4.83700
HOT RADIUS = 0.0
DATE 11/18/87 TIME 17:28:14
THERMAL SHRINK FACTOR = 1.000000
CYLINDRICAL

PRETMIST NOT USED FOR TD PRINTOUT.

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0.010	-0.18199	0.05623		-0.16199	0.01604	
0.020	-0.17831	0.06402		-0.17831	0.01026	
0.030	-0.17463	0.06991		-0.17463	0.00438	
0.040	-0.17095	0.07279		-0.17095	-0.00051	
0.050	-0.16727	0.07904		-0.16727	-0.00476	
0.060	-0.16359	0.08281		-0.16359	-0.00853	
0.070	-0.15991	0.08623		-0.15991	-0.01195	
0.080	-0.15623	0.08936		-0.15623	-0.01508	
0.090	-0.15255	0.09226		-0.15255	-0.01798	
0.100	-0.14887	0.09494		-0.14887	-0.02067	
0.125	-0.13967	0.10094		-0.13967	-0.02666	
0.150	-0.13047	0.10612		-0.13047	-0.03184	
0.175	-0.12127	0.11065		-0.12127	-0.03537	
0.200	-0.11207	0.11464		-0.11207	-0.04036	
0.225	-0.10287	0.11817		-0.10287	-0.04389	
0.250	-0.092167	0.12131		-0.09367	-0.04703	
0.275	-0.08447	0.12408		-0.08447	-0.04984	
0.300	-0.07527	0.12648		-0.07527	-0.05271	
0.325	-0.06607	0.12848		-0.06607	-0.05578	
0.350	-0.05687	0.13004		-0.05687	-0.05894	
0.375	-0.04767	0.13116		-0.04767	-0.06250	
0.400	-0.03847	0.13181		-0.03847	-0.06617	
0.425	-0.02927	0.13195		-0.02927	-0.07006	
0.450	-0.02097	0.13155		-0.02097	-0.07417	
0.475	-0.01087	0.13057		-0.01087	-0.07853	
0.500	-0.00167	0.12898		-0.00167	-0.08314	
0.525	0.00753	0.12672		0.00753	-0.08801	
0.550	0.01673	0.12373		0.01673	-0.09318	
0.575	0.02593	0.11994		0.02593	-0.09865	
0.600	0.03513	0.11526		0.03513	-0.10444	
0.625	0.04433	0.10964		0.04433	-0.11059	
0.650	0.05353	0.10291		0.05353	-0.11713	
0.675	0.06273	0.09494		0.06273	-0.12410	
0.700	0.07193	0.08553		0.07193	-0.13153	
0.725	0.08113	0.07445		0.08113	-0.13950	
0.750	0.09033	0.06135		0.09033	-0.14806	
0.775	0.09953	0.04577		0.09953	-0.15733	
0.800	0.10873	0.02713		0.10873	-0.16741	
0.825	0.11793	0.00484		0.11793	-0.17849	
0.850	0.12713	-0.02158		0.12713	-0.19082	
0.875	0.13633	-0.02526		0.13633	-0.20476	
0.900	0.14553	-0.08740		0.14553	-0.22106	
0.920	0.14921	-0.10253		0.14921	-0.22848	
0.930	0.15289	-0.11824		0.15289	-0.23662	
0.940	0.15657	-0.13451		0.15657	-0.24571	
0.950	0.16025	-0.15128		0.16025	-0.25614	
0.950	0.16393	-0.16853		0.16393	-0.26691	
1.000	0.16233	-0.26023		0.16233	-0.26734	

INLET ANGLE (DEG.) 159.717
INLET MEDGE ANGLE (DEG.) 65.161
EXIT ANGLE (DEG.) 108.355
RAD. REF. PT. (X,Y) 0.0 0.0
UNCOVERED TURNING ANGLE (DEG.) 21.131
AXIAL CHORD 0.36800
ACTUAL CHORD 0.48506
PITCH 0.37063
NO. OF FOILS 82

NO. 1 COR. ANTOUR
TD 0 TD REV. 0 PART NO.
SUBTITLE

TITLE - ATD LOX 1V

EMD NO.

HOT RADIUS = 4.83700

DATE 11/10/87 TIME 17:28:14
COLD RADIUS = 0.0 THERMAL SHRINK FACTOR = 1.00000

PRETEST NOT USED FOR TD PRINTOUT.

PCT X	X TOP	Y TOP	(CIRCLE)	X BOT	Y BOT	(CIRCLE)
0.0	-0.13267	0.06471	0.03726	-0.13247	0.03017	0.03726
0.010	-0.13032	0.04633	0.04497	-0.13032	0.02639	0.02952
0.020	-0.12817	0.04794	0.04774	-0.12817	0.02663	0.02675
0.030	-0.12603	0.04956		-0.12603	0.02689	
0.040	-0.12388	0.05117		-0.12388	0.02319	
0.050	-0.12173	0.05274		-0.12173	0.02155	
0.060	-0.11958	0.05426		-0.11958	0.01999	
0.070	-0.11744	0.05571		-0.11744	0.01850	
0.080	-0.11529	0.05711		-0.11529	0.01708	
0.090	-0.11314	0.05845		-0.11314	0.01573	
0.100	-0.11099	0.05973		-0.11099	0.01446	
0.125	-0.10563	0.06270		-0.10563	0.01156	
0.150	-0.10026	0.06532		-0.10026	0.00898	
0.175	-0.09489	0.06767		-0.09489	0.00665	
0.200	-0.08952	0.06980		-0.08952	0.00451	
0.225	-0.08415	0.07176		-0.08415	0.00253	
0.250	-0.07878	0.07357		-0.07878	0.00170	
0.275	-0.07341	0.07523		-0.07341	-0.00101	
0.300	-0.06805	0.07674		-0.06805	-0.00266	
0.325	-0.06268	0.07807		-0.06268	-0.00429	
0.350	-0.05731	0.07923		-0.05731	-0.00597	
0.375	-0.05194	0.08021		-0.05194	-0.00774	
0.400	-0.04657	0.08098		-0.04657	-0.00959	
0.425	-0.04120	0.08154		-0.04120	-0.01151	
0.450	-0.03583	0.08188		-0.03583	-0.01350	
0.475	-0.03046	0.08196		-0.03046	-0.01555	
0.500	-0.02510	0.08178		-0.02510	-0.01766	
0.525	-0.01973	0.08130		-0.01973	-0.01982	
0.550	-0.01436	0.08051		-0.01436	-0.02206	
0.575	-0.00899	0.07938		-0.00899	-0.02436	
0.600	-0.00362	0.07786		-0.00362	-0.02673	
0.625	0.00175	0.07592		0.00175	-0.02918	
0.650	0.00712	0.07353		0.00712	-0.03170	
0.675	0.01249	0.07063		0.01249	-0.03429	
0.700	0.01785	0.06716		0.01785	-0.03697	
0.725	0.02322	0.06312		0.02322	-0.03972	
0.750	0.02859	0.05860		0.02859	-0.04256	
0.775	0.03396	0.05296		0.03396	-0.04549	
0.800	0.03933	0.04674		0.03933	-0.04850	
0.825	0.04470	0.03943		0.04470	-0.05160	
0.850	0.05007	0.03152		0.05007	-0.05480	
0.875	0.05544	0.02221		0.05544	-0.05810	
0.900	0.06080	0.01157		0.06080	-0.06150	-0.06137
0.910	0.06295	0.00693		0.06295	-0.06269	-0.06220
0.920	0.06510	0.00206		0.06510	-0.06430	-0.06268
0.930	0.06725	-0.00305		0.06725	-0.06572	-0.06284
0.940	0.06939	-0.00840		0.06939	-0.06717	-0.06269
0.950	0.07154	-0.01399		0.07154	-0.06863	-0.06222
0.960	0.07369	-0.01981		0.07369	-0.07011	-0.06160
0.970	0.07584	-0.02586		0.07584	-0.07160	-0.06016
0.980	0.07798	-0.03218		0.07798	-0.07312	-0.05935
0.990	0.08013	-0.03874		0.08013	-0.07466	-0.05558
1.000	0.08228	-0.04557		0.08228	-0.07622	-0.04785

EXTERNAL - FOUR
TD 0 TD REV. 0 PART NO. TITLE - STD LOX IV
SUBTITLE

DATE 11/18/87 TIME 17:28:14
COLD RADIUS = 0.0 THERMAL SHRINK FACTOR = 1.00000

PREMIST NOT USED FOR TD PRINTOUT.

PCT	X	X TOP	Y TOP	(CIRCLE)	X BOT	Y BOT	(CIRCLE)
0.0	-0.18567	0.03674	0.03376	-0.18567	0.03374	0.03374	0.03374
0.010	-0.18186	0.05317	-0.18186	0.05317	-0.17895	0.05640	0.05640
0.020	-0.17905	0.06100	-0.17905	0.06100	-0.17624	0.06442	0.06442
0.030	-0.17624	0.06706	-0.17624	0.06706	-0.17343	0.06955	0.06955
0.040	-0.17063	0.07223	-0.17063	0.07223	-0.16682	0.07633	0.07633
0.050	-0.16662	0.07633	-0.16662	0.07633	-0.16281	0.08017	0.08017
0.060	-0.16281	0.08017	-0.16281	0.08017	-0.15900	0.08363	0.08363
0.070	-0.15900	0.08660	-0.15900	0.08660	-0.15519	0.09019	0.09019
0.080	-0.15519	0.08660	-0.15519	0.08660	-0.15138	0.08973	0.08973
0.090	-0.15138	0.08973	-0.15138	0.08973	-0.14757	0.09245	0.09245
0.100	-0.14757	0.09245	-0.14757	0.09245	-0.13965	0.09851	0.09851
0.125	-0.13805	0.10373	-0.13805	0.10373	-0.12652	0.10828	0.10828
0.150	-0.12852	0.11190	-0.12852	0.11190	-0.11900	0.11900	0.11900
0.175	-0.11900	0.12166	-0.11900	0.12166	-0.10947	0.12396	0.12396
0.200	-0.10947	0.11228	-0.10947	0.11228	-0.09935	0.11581	0.11581
0.225	-0.09935	0.11581	-0.09935	0.11581	-0.09090	0.11823	0.11823
0.250	-0.09090	0.12166	-0.09090	0.12166	-0.08090	0.12396	0.12396
0.275	-0.08090	0.12396	-0.08090	0.12396	-0.07137	0.12582	0.12582
0.300	-0.07137	0.12582	-0.07137	0.12582	-0.06185	0.12721	0.12721
0.325	-0.06185	0.12721	-0.06185	0.12721	-0.05232	0.12771	0.12771
0.350	-0.05232	0.12771	-0.05232	0.12771	-0.04280	0.12811	0.12811
0.375	-0.04280	0.12811	-0.04280	0.12811	-0.03327	0.12850	0.12850
0.400	-0.03327	0.12850	-0.03327	0.12850	-0.02575	0.12886	0.12886
0.425	-0.02575	0.12886	-0.02575	0.12886	-0.01422	0.12745	0.12745
0.450	-0.01422	0.12745	-0.01422	0.12745	-0.00470	0.12634	0.12634
0.475	-0.00470	0.12634	-0.00470	0.12634	0.00463	0.12539	0.12539
0.500	0.00463	0.12539	0.00463	0.12539	0.01435	0.12175	0.12175
0.525	0.01435	0.12175	0.01435	0.12175	0.02386	0.11637	0.11637
0.550	0.02386	0.11637	0.02386	0.11637	0.03340	0.11420	0.11420
0.575	0.03340	0.11420	0.03340	0.11420	0.04293	0.10915	0.10915
0.600	0.04293	0.10915	0.04293	0.10915	0.05245	0.10313	0.10313
0.625	0.05245	0.10313	0.05245	0.10313	0.06194	0.09405	0.09405
0.650	0.06194	0.09405	0.06194	0.09405	0.07150	0.08775	0.08775
0.675	0.07150	0.08775	0.07150	0.08775	0.08103	0.07907	0.07907
0.700	0.08103	0.07907	0.08103	0.07907	0.09195	0.07807	0.07807
0.725	0.09055	0.06679	0.09055	0.06679	0.10960	0.05807	0.05807
0.750	0.10008	0.05159	0.10008	0.05159	0.11913	0.04193	0.04193
0.775	0.10960	0.03807	0.10960	0.03807	0.12865	0.02233	0.02233
0.800	0.11913	0.01943	0.11913	0.01943	0.13818	0.00233	0.00233
0.825	0.12865	-0.00233	0.12865	-0.00233	0.14818	-0.02233	-0.02233
0.850	0.13818	-0.02233	0.13818	-0.02233	0.15818	-0.04193	-0.04193
0.875	0.14770	-0.06011	0.14770	-0.06011	0.16866	-0.09662	-0.09662
0.900	0.16866	-0.14717	0.16866	-0.14717	0.18771	-0.17447	-0.17447
0.940	0.17247	-0.16553	0.17247	-0.16553	0.19152	-0.20652	-0.20652
0.950	0.17628	-0.18458	0.17628	-0.18458	0.17628	-0.23170	-0.23170
0.960	0.18009	-0.20428	0.18009	-0.20428	0.18009	-0.22979	-0.22979
0.970	0.18390	-0.22457	0.18390	-0.22457	0.18390	-0.29355	-0.29355
0.980	0.18771	-0.24562	0.18771	-0.24562	0.18771	-0.2916	-0.2916
0.990	0.19152	-0.26678	0.19152	-0.26678	0.19152	-0.29370	-0.29370
1.000	0.19533	-0.28813	0.19533	-0.28813	0.19533	-0.29545	-0.29545

NO. 1 CORL JNTOUR
TD 0 TD REV. 0 PART NO.
SUBTITLE DATE 11/18/87 TIME 17:26:14
TITLE - ATD LOK IV
EMD NO. COLD RADIUS = 0.0
HOT RADIUS = 4.97300 THERMAL SHRINK FACTOR = 1.00000

PREVIEW NOT USED FOR TD PRINTOUT.

PCT X	X TOP	Y TOP	(CIRCLE)	X BOT	Y BOT	(CIRCLE)
0.0	-0.13237	0.04104	0.03376	-0.13237	0.02652	0.03376
0.010	-0.13010	0.04285	0.04169	-0.13010	0.02469	0.02580
0.020	-0.12782	0.04463	0.04451	-0.12782	0.02287	0.02298
0.030	-0.12555	0.04639		-0.12555	0.02108	
0.040	-0.12327	0.04812		-0.12327	0.01933	
0.050	-0.12100	0.04980		-0.12100	0.01763	
0.060	-0.11873	0.05140		-0.11873	0.01601	
0.070	-0.11645	0.05294		-0.11645	0.01447	
0.080	-0.11418	0.05441		-0.11418	0.01301	
0.090	-0.11190	0.05580		-0.11190	0.01161	
0.100	-0.10963	0.05713		-0.10963	0.01030	
0.125	-0.10394	0.06017		-0.10394	0.00730	
0.150	-0.09826	0.06284		-0.09826	0.00464	
0.175	-0.09257	0.06522		-0.09257	0.00230	
0.200	-0.08689	0.06738		-0.08689	0.00015	
0.225	-0.08120	0.06937		-0.08120	-0.00194	
0.250	-0.07552	0.07120		-0.07552	-0.00371	
0.275	-0.06984	0.07286		-0.06984	-0.00552	
0.300	-0.06415	0.07432		-0.06415	-0.00730	
0.325	-0.05847	0.07559		-0.05847	-0.00910	
0.350	-0.05278	0.07664		-0.05278	-0.01094	
0.375	-0.04710	0.07748		-0.04710	-0.01286	
0.400	-0.04141	0.07807		-0.04141	-0.01488	
0.425	-0.03573	0.07843		-0.03573	-0.01699	
0.450	-0.03004	0.07852		-0.03004	-0.01918	
0.475	-0.02436	0.07853		-0.02436	-0.02146	
0.500	-0.01867	0.07784		-0.01867	-0.02360	
0.525	-0.01299	0.07703		-0.01299	-0.02621	
0.550	-0.00720	0.07588		-0.00720	-0.02870	
0.575	-0.00162	0.07435		-0.00162	-0.03127	
0.600	0.00407	0.07243		0.00407	-0.03392	
0.625	0.00975	0.07007		0.00975	-0.03666	
0.650	0.01544	0.06724		0.01544	-0.03929	
0.675	0.02112	0.06391		0.02112	-0.04261	
0.700	0.02601	0.06003		0.02601	-0.04562	
0.725	0.03249	0.05556		0.03249	-0.04853	
0.750	0.03818	0.05064		0.03818	-0.05174	
0.775	0.04386	0.04461		0.04386	-0.05505	
0.800	0.04955	0.03802		0.04955	-0.05847	
0.825	0.05523	0.03058		0.05523	-0.06199	
0.850	0.06092	0.02215		0.06092	-0.06533	
0.875	0.06660	0.01255		0.06660	-0.06939	
0.900	0.07229	0.00162		0.07229	-0.07327	-0.07324
0.910	0.07456	-0.00315		0.07456	-0.07486	-0.07435
0.920	0.07684	-0.00816		0.07684	-0.07647	-0.07594
0.930	0.07911	-0.01343		0.07911	-0.07810	-0.07515
0.940	0.08139	-0.01697		0.08139	-0.07975	-0.07332
0.950	0.08366	-0.02477		0.08366	-0.08162	-0.07693
0.960	0.08523	-0.03084		0.08523	-0.08311	-0.07416
0.970	0.08821	-0.03720		0.08821	-0.08483	-0.07295
0.980	0.09048	-0.04386		0.09048	-0.08657	-0.07113
0.990	0.09276	-0.05083		0.09276	-0.08834	-0.06831
1.000	0.09503	-0.05811	-0.06037	0.09503	-0.09013	-0.06037

EXTERNAL L-TOUR
TD 0 TD REV. 0 PART NO. TITLE - ATD LOX 1V
SUBTITLE COLD RADIUS = 5.11000 TIME 17:28:14 CYLINDRICAL

DATE 11/18/87 THERMAL SHRINK FACTOR = 1.00000
EMD NO. HOT RADIUS = 5.11000

PRETEXT NOT USED FOR TD PRINTOUT.

PCT X	X TOP	Y TOP	(CIRCLE)	X BOT	Y BOT	(CIRCLE)
0.0	-0.14547	0.04239	0.03939	-0.14567	0.03619	0.03939
0.010	-0.18173	0.05914		-0.18173	0.01944	
0.020	-0.17779	0.06716		-0.17779	0.01160	
0.030	-0.17385	0.07326		-0.17385	0.00552	
0.040	-0.16991	0.07830		-0.16991	0.00464	
0.050	-0.16597	0.08267		-0.16597	-0.00389	
0.060	-0.16203	0.08655		-0.16203	-0.00777	
0.070	-0.15809	0.09006		-0.15809	-0.01128	
0.080	-0.15415	0.09328		-0.15415	-0.01650	
0.090	-0.15021	0.09624		-0.15021	-0.01746	
0.100	-0.14627	0.09899		-0.14627	-0.02021	
0.125	-0.13642	0.10511		-0.13642	-0.02633	
0.150	-0.12657	0.11036		-0.12657	-0.03158	
0.175	-0.11672	0.11493		-0.11672	-0.03615	
0.200	-0.10687	0.11894		-0.10687	-0.04016	
0.225	-0.09702	0.12246		-0.09702	-0.04368	
0.250	-0.08717	0.12555		-0.08717	-0.04678	
0.275	-0.07732	0.12817		-0.07732	-0.04981	
0.300	-0.06747	0.13025		-0.06747	-0.05308	
0.325	-0.05762	0.13177		-0.05762	-0.05658	
0.350	-0.04777	0.13274		-0.04777	-0.06032	
0.375	-0.03792	0.13316		-0.03792	-0.06432	
0.400	-0.02807	0.13301		-0.02807	-0.06857	
0.425	-0.01822	0.13227		-0.01822	-0.07309	
0.450	-0.00837	0.13094		-0.00837	-0.07790	
0.475	0.00148	0.12699		0.00148	-0.08300	
0.500	0.01133	0.12640		0.01133	-0.08642	
0.525	0.02118	0.12313		0.02118	-0.09416	
0.550	0.03103	0.11916		0.03103	-0.10025	
0.575	0.04088	0.11439		0.04088	-0.10672	
0.600	0.05073	0.10881		0.05073	-0.11359	
0.625	0.06058	0.10234		0.06058	-0.12089	
0.650	0.07043	0.09687		0.07043	-0.12866	
0.675	0.08028	0.08630		0.08028	-0.13694	
0.700	0.09013	0.07646		0.09013	-0.14579	
0.725	0.09998	0.06514		0.09998	-0.15528	
0.750	0.10283	0.05203		0.10283	-0.16548	
0.775	0.11968	0.03669		0.11968	-0.17651	
0.800	0.12953	0.01943		0.12953	-0.18852	
0.825	0.13938	-0.00366		0.13938	-0.20168	
0.850	0.14923	-0.03054		0.14923	-0.21629	
0.875	0.15908	-0.06300		0.15908	-0.23276	
0.900	0.16893	-0.10136		0.16893	-0.25181	
0.910	0.17287	-0.11630		0.17287	-0.26042	
0.920	0.17681	-0.13610		0.17681	-0.26978	
0.930	0.18075	-0.15469		0.18075	-0.28012	
0.940	0.18469	-0.17401		0.18469	-0.29175	
0.950	0.18863	-0.19401		0.18863	-0.30528	
0.960	0.19257	-0.21462		0.19257	-0.31103	
0.970	0.19651	-0.23578		0.19651	-0.31268	
0.980	0.20045	-0.25743		0.20045	-0.31262	
0.990	0.20439	-0.27951		0.20439	-0.31061	
1.000	0.20833	-0.30160		0.20833	-0.30251	

NO. 1 COLD - CONTOUR
TD 0 TD REV. 0 PART NO. TITLE - ATD LOK IV
SUBTITLE

DATE 11/18/87 TIME 17:28:14 CYLINDRICAL
EMD NO. 5.11000 COLD RADIUS = 0.0 THERMAL SHRINK FACTOR = 1.00000

PRETHRUST NOT USED FOR TD PRINTOUT.

PCT X	X TOP	Y TOP	(CIRCLE)	X BOT	Y BOT	(CIRCLE)
0.0	-0.13232	0.04668	0.03949	-0.13232	0.03251	0.03249
0.010	-0.12993	0.04873	0.04761	-0.12993	0.03136	0.03136
0.020	-0.12755	0.05056	0.05047	-0.12755	0.02846	0.02850
0.030	-0.12516	0.05238		-0.12516	0.02652	
0.040	-0.12278	0.05416		-0.12278	0.02465	
0.050	-0.12039	0.05589		-0.12039	0.02286	
0.060	-0.11801	0.05754		-0.11801	0.02116	
0.070	-0.11562	0.05911		-0.11562	0.01956	
0.080	-0.11324	0.06061		-0.11324	0.01804	
0.090	-0.11085	0.06205		-0.11085	0.01661	
0.100	-0.10846	0.06341		-0.10846	0.01527	
0.125	-0.10250	0.06452		-0.10250	0.01223	
0.150	-0.09654	0.06925		-0.09654	0.00957	
0.175	-0.09057	0.07166		-0.09057	0.00719	
0.200	-0.08461	0.07385		-0.08461	0.00501	
0.225	-0.07865	0.07587		-0.07865	0.00298	
0.250	-0.07268	0.07769		-0.07268	0.00105	
0.275	-0.06672	0.07929		-0.06672	-0.00084	
0.300	-0.06076	0.08063		-0.06076	-0.00273	
0.325	-0.05479	0.08169		-0.05479	-0.00464	
0.350	-0.04883	0.08264		-0.04883	-0.00643	
0.375	-0.04286	0.08396		-0.04286	-0.00972	
0.400	-0.03690	0.08516		-0.03690	-0.01091	
0.425	-0.03094	0.08636		-0.03094	-0.01320	
0.450	-0.02497	0.08769		-0.02497	-0.01558	
0.475	-0.01901	0.08899		-0.01901	-0.01803	
0.500	-0.01305	0.08998		-0.01305	-0.02057	
0.525	-0.00708	0.07962		-0.00708	-0.02319	
0.550	-0.00112	0.07792		-0.00112	-0.02520	
0.575	0.00485	0.07584		0.00485	-0.02669	
0.600	0.01081	0.07341		0.01081	-0.03159	
0.625	0.01677	0.07057		0.01677	-0.03458	
0.650	0.02274	0.06730		0.02274	-0.03760	
0.675	0.02870	0.06358		0.02870	-0.04088	
0.700	0.03466	0.05937		0.03466	-0.04418	
0.725	0.04063	0.05463		0.04063	-0.04758	
0.750	0.04659	0.04933		0.04659	-0.05110	
0.775	0.05256	0.04341		0.05256	-0.05473	
0.800	0.05852	0.03681		0.05852	-0.05848	
0.825	0.06448	0.02945		0.06448	-0.06236	
0.850	0.07045	0.02216		0.07045	-0.06636	
0.900	0.08237	0.00884		0.08237	-0.07477	-0.07477
0.910	0.08476	-0.00392		0.08476	-0.07652	-0.07617
0.920	0.08715	-0.00995		0.08715	-0.07829	-0.07705
0.930	0.08953	-0.01426		0.08953	-0.08009	-0.07751
0.940	0.09192	-0.01987		0.09192	-0.08191	-0.07758
0.950	0.09430	-0.02570		0.09430	-0.08376	-0.07727
0.960	0.09669	-0.03199		0.09669	-0.08563	-0.07655
0.970	0.09907	-0.03852		0.09907	-0.08753	-0.07535
0.980	0.10146	-0.04540		0.10146	-0.08945	-0.07353
0.990	0.10384	-0.05265		0.10384	-0.09140	-0.07067
1.000	0.10623	-0.06026	-0.06253	0.10623	-0.09338	-0.06253

EXTERNAL L. -SOUR
TD O TD REV. O PART NO.
SUBTITLE

TITLE - ATO LOX IV
END NO.
HOT RADIUS = 5.24700
COLD RADIUS = 0.0
THERMAL SHRINK FACTOR = 1.000000

PRENTIST NOT USED FOR TD PRINTOUT.

PCT X	X TOP	Y TOP	(CIRCLE)	X BOT	Y BOT	(CIRCLE)
0.0	-0.18567	0.05459	0.06158	-0.18567	0.06158	0.05158
0.010	-0.18161	0.07163		-0.18161	0.03154	
0.020	-0.17755	0.07979		-0.17755	0.02358	
0.030	-0.17349	0.08595		-0.17349	0.01722	
0.040	-0.16943	0.09106		-0.16943	0.01211	
0.050	-0.16537	0.09548		-0.16537	0.00769	
0.060	-0.16131	0.09941		-0.16131	0.00376	
0.070	-0.15725	0.10297		-0.15725	0.00020	
0.080	-0.15319	0.10621		-0.15319	-0.00304	
0.090	-0.14913	0.10921		-0.14913	-0.00604	
0.100	-0.14507	0.11198		-0.14507	-0.00901	
0.125	-0.13692	0.11615		-0.13492	-0.01498	
0.150	-0.12677	0.12344		-0.12677	-0.02027	
0.175	-0.11462	0.12802		-0.11462	-0.02485	
0.200	-0.10447	0.13203		-0.10447	-0.02886	
0.225	-0.09432	0.13554		-0.09432	-0.03237	
0.250	-0.08617	0.13860		-0.08617	-0.03548	
0.275	-0.07402	0.14111		-0.07402	-0.03667	
0.300	-0.06387	0.14302		-0.06387	-0.04208	
0.325	-0.05372	0.14433		-0.05372	-0.04572	
0.350	-0.04357	0.14505		-0.04357	-0.04960	
0.375	-0.03342	0.14518		-0.03342	-0.05373	
0.400	-0.02327	0.14470		-0.02327	-0.05811	
0.425	-0.01312	0.14360		-0.01312	-0.06275	
0.450	-0.00297	0.14186		-0.00297	-0.06767	
0.475	0.00718	0.13947		0.00718	-0.07289	
0.500	0.01733	0.13640		0.01733	-0.07961	
0.525	0.02746	0.13260		0.02746	-0.08425	
0.550	0.03763	0.12805		0.03763	-0.09044	
0.575	0.04778	0.12266		0.04778	-0.09699	
0.600	0.05793	0.11664		0.05793	-0.10394	
0.625	0.06808	0.10923		0.06808	-0.11130	
0.650	0.07823	0.10095		0.07823	-0.11913	
0.675	0.08838	0.09147		0.08838	-0.12745	
0.700	0.09853	0.08059		0.09853	-0.13633	
0.725	0.10868	0.06805		0.10868	-0.14582	
0.750	0.11883	0.05347		0.11883	-0.15601	
0.775	0.12898	0.03627		0.12898	-0.16699	
0.800	0.13913	0.01568		0.13913	-0.17690	
0.825	0.14928	-0.00900		0.14928	-0.19191	
0.850	0.15943	-0.03824		0.15943	-0.20626	
-0.875	0.16958	-0.07206		0.16958	-0.22234	
0.900	0.17973	-0.11000		0.17973	-0.24074	
0.920	0.18785	-0.16282		0.18785	-0.25783	
0.930	0.19191	-0.15993		0.19191	-0.26749	
0.940	0.19597	-0.17743		0.19597	-0.27017	
0.950	0.20003	-0.19528		0.20003	-0.29025	
0.960	0.20409	-0.21346		0.20409	-0.29752	
0.970	0.20815	-0.23191		0.20815	-0.29947	
-0.980	0.21221	-0.25061		0.21221	-0.29953	
0.990	0.21627	-0.26924		0.21627	-0.29775	-0.29760
1.000	0.22033	-0.28947	-0.28954	0.22033	-0.29598	-0.28954

NO. 1 COLD - CONTOUR
TD 0 TD REV. 0 PART NO. END NO.
SUBTITLE HOT RADIUS = 5.24700 COLD RADIUS = 0.0

TITLE - ATO LOK IV DATE 11/18/87 TIME 17:28:14
COLD RADIUS = 0.0 THERMAL SHRINK FACTOR = 1.00000

PRETMIST NOT USED FOR TD PRINTOUT.

PCT	X	X TOP	Y TOP	(CIRCLE)	X BOT	Y BOT	(CIRCLE)
0.0	-0.13277	0.05927	0.05116	-0.13277	0.06316	0.05116	
0.010	-0.13034	0.06029	0.05934	-0.13034	0.06153	0.04298	
0.020	-0.12791	0.06226	0.06221	-0.12791	0.03990	0.04011	
0.030	-0.12549	0.06418	0.06418	-0.12549	0.03827		
0.040	-0.12306	0.06605	0.06605	-0.12306	0.03665		
0.050	-0.12063	0.06785	0.06785	-0.12063	0.03503		
0.060	-0.11820	0.06957	0.06957	-0.11820	0.03344		
0.070	-0.11577	0.07120	0.07120	-0.11577	0.03189		
0.080	-0.11335	0.07274	0.07274	-0.11335	0.03039		
0.090	-0.11092	0.07424	0.07424	-0.11092	0.02896		
0.100	-0.10849	0.07563	0.07563	-0.10849	0.02760		
0.125	-0.10242	0.07878	0.07878	-0.10242	0.02445		
0.150	-0.09635	0.08153	0.08153	-0.09635	0.02167		
0.175	-0.09028	0.08396	0.08396	-0.09028	0.01920		
0.200	-0.08421	0.08618	0.08618	-0.08421	0.01698		
0.225	-0.07814	0.08823	0.08823	-0.07814	0.01497		
0.250	-0.07207	0.09006	0.09006	-0.07207	0.01307		
0.275	-0.06600	0.09165	0.09165	-0.06600	0.01122		
0.300	-0.05993	0.09296	0.09296	-0.05993	0.00933		
0.325	-0.05386	0.09397	0.09397	-0.05386	0.00735		
0.350	-0.04779	0.09467	0.09467	-0.04779	0.00528		
0.375	-0.04172	0.09508	0.09508	-0.04172	0.00313		
0.400	-0.03565	0.09520	0.09520	-0.03565	0.00091		
0.425	-0.02958	0.09501	0.09501	-0.02958	-0.00140		
0.450	-0.02351	0.09451	0.09451	-0.02351	-0.00377		
0.475	-0.01744	0.09369	0.09369	-0.01744	-0.00623		
0.500	-0.01137	0.09254	0.09254	-0.01137	-0.00877		
0.525	-0.00530	0.09105	0.09105	-0.00530	-0.01139		
0.550	0.00077	0.08922	0.08922	0.00077	-0.01409		
0.575	0.00684	0.08701	0.08701	0.00684	-0.01688		
0.600	0.01291	0.08443	0.08443	0.01291	-0.01977		
0.625	0.01898	0.08146	0.08146	0.01898	-0.02274		
0.650	0.02505	0.07806	0.07806	0.02505	-0.02582		
0.675	0.03112	0.07423	0.07423	0.03112	-0.02899		
0.700	0.03719	0.06991	0.06991	0.03719	-0.03225		
0.725	0.04326	0.06507	0.06507	0.04326	-0.03563		
0.750	0.04933	0.05967	0.05967	0.04933	-0.03910		
0.775	0.05540	0.05367	0.05367	0.05540	-0.04269		
0.800	0.06147	0.04700	0.04700	0.06147	-0.04638		
0.825	0.06754	0.03960	0.03960	0.06754	-0.05020		
0.850	0.07361	0.03131	0.03131	0.07361	-0.05413		
0.875	0.07968	0.02188	0.02188	0.07968	-0.05818		
0.900	0.08575	0.01107	0.01107	0.08575	-0.06237		
0.910	0.08818	0.00633	0.00633	0.08818	-0.06408		
0.920	0.09061	0.00133	0.00133	0.09061	-0.06591		
0.930	0.09303	-0.00393	-0.00393	0.09303	-0.06757		
0.940	0.09546	-0.00946	-0.00946	0.09546	-0.06936		
0.950	0.09789	-0.01525	-0.01525	0.09789	-0.07116		
0.960	0.10032	-0.02126	-0.02126	0.10032	-0.07299		
0.970	0.10275	-0.02757	-0.02757	0.10275	-0.07483		
0.980	0.10517	-0.03413	-0.03413	0.10517	-0.07671		
0.990	0.10760	-0.04096	-0.04096	0.10760	-0.07861		
1.000	0.11003	-0.04807	-0.05053	0.11003	-0.08054		

K-E 10 X 10 TO $\frac{1}{4}$ INCH 7 X 10 INCHES
KEUFFEL & ESSER CO. MADE IN U.S.A.

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225000 225000 225000 225000 225000

GIVING DISTANCE (INCHES)

DF117427

P824 UTILITY PROGRAM - FLOW AREA CALCULATION

ATD LOK IV
HOT TO COLD CONVERSION RADII

HOT COLD
4.70000 4.00000
5.20050 5.25500
RESTALLER ANGLE DEGREES : 0.0 RADIANS : 0.0
PLATFORM RADII : LE IN : 4.30000 LL OD : 4.30000
TE ID : 5.70000 TE OD : 5.70000
GAGING RADII : INNER : 4.70000 OUTER : 5.06742
NUMBER OF BLADES FOR GAGING : 85
STAGGER IN INCHES IS 3.00 TO 3.00 IN INCREMENTS OF 0.50
IN CLASS IS -6 TO +6
TOLER : 0.0

STAGGER (DEGREE)	HOT FLOW (150 IN)	FLOW AREA (150 IN)
-7.00000	3.24510	-19.67870
-2.50000	3.17801	-16.28404
-1.00000	3.51077	-15.16402
-1.50000	3.64322	-9.82178
-1.00000	3.77578	-6.54359
-0.50000	3.90804	-5.26980

0.0 4.04015 0.0 3.97182 → PHYSICAL GAGE AREA WITHOUT FICET RADII

0.50000	4.17197	3.26282
1.00000	4.30561	6.55105
1.50000	4.43500	9.77332
2.00000	4.56610	13.01810
2.50000	4.69686	16.25468
3.00000	4.82758	19.46772

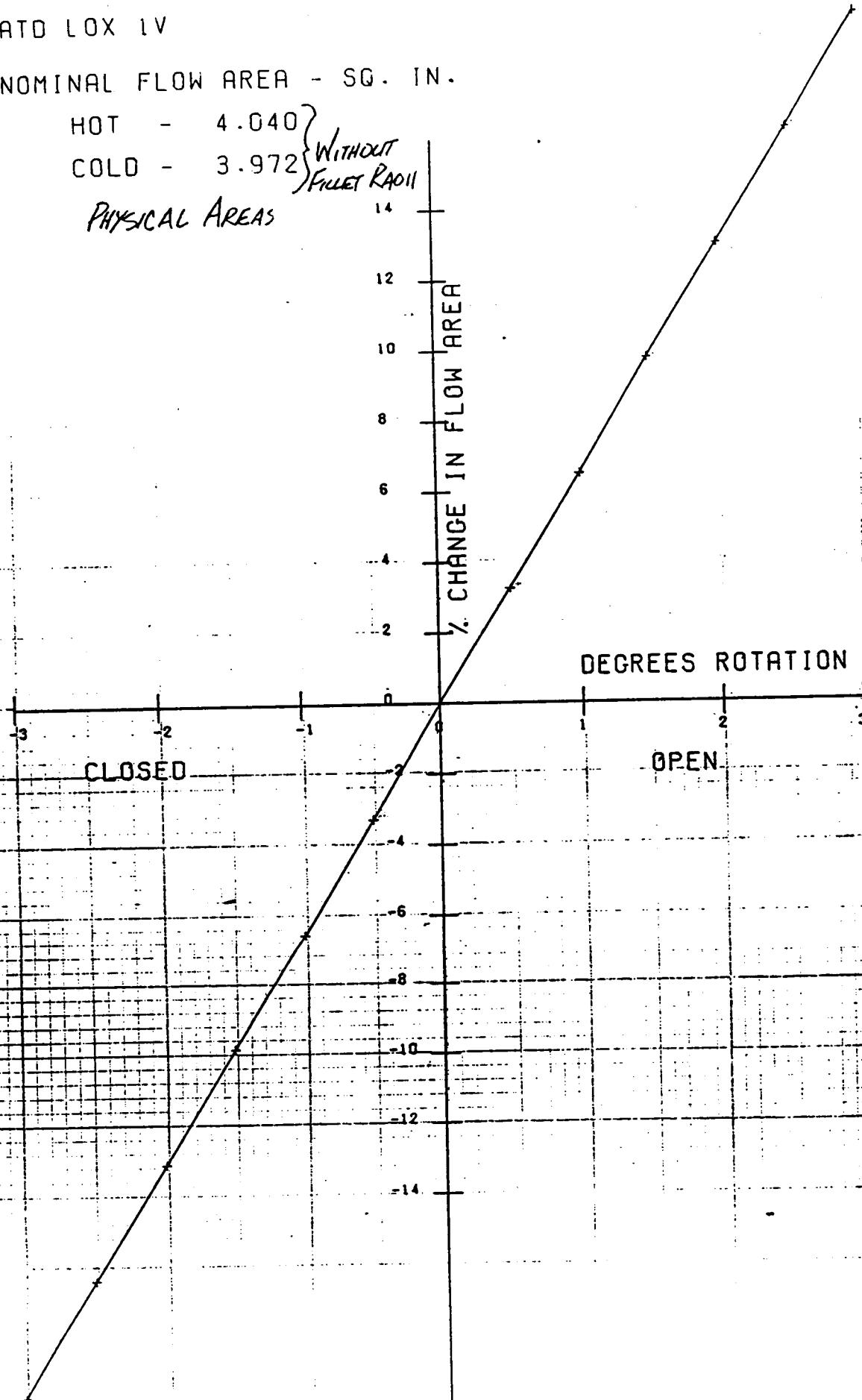
ATD LOX LV

NOMINAL FLOW AREA - SQ. IN.

HOT - 4.040
COLD - 3.972

} WITHOUT
} FILLET RADIUS

PHYSICAL AREAS



P024 UTILITY PROGRAM - STRESS CALCULATION

ATO LOX IV
ENGINE OPERATING CONDITION
NAME : ADP
REH : TITLE
1 66.0 0. ADP
XGSR = 0.00100 XGRH = -3.96100 XGRT = 0.00100
YGSR = 0.00100 YGRH = -27.24899 YGRT = 0.00100
DENSITY = 0.31200 MESH TITING RADIJ INNER = 6.3146
SHROUD VOLUME = 0.0 SHROUD THICKNESS = 0.0
SHROUD MISALIGNMENT = 0.0 RADIUS OF SHROUD = 0.0

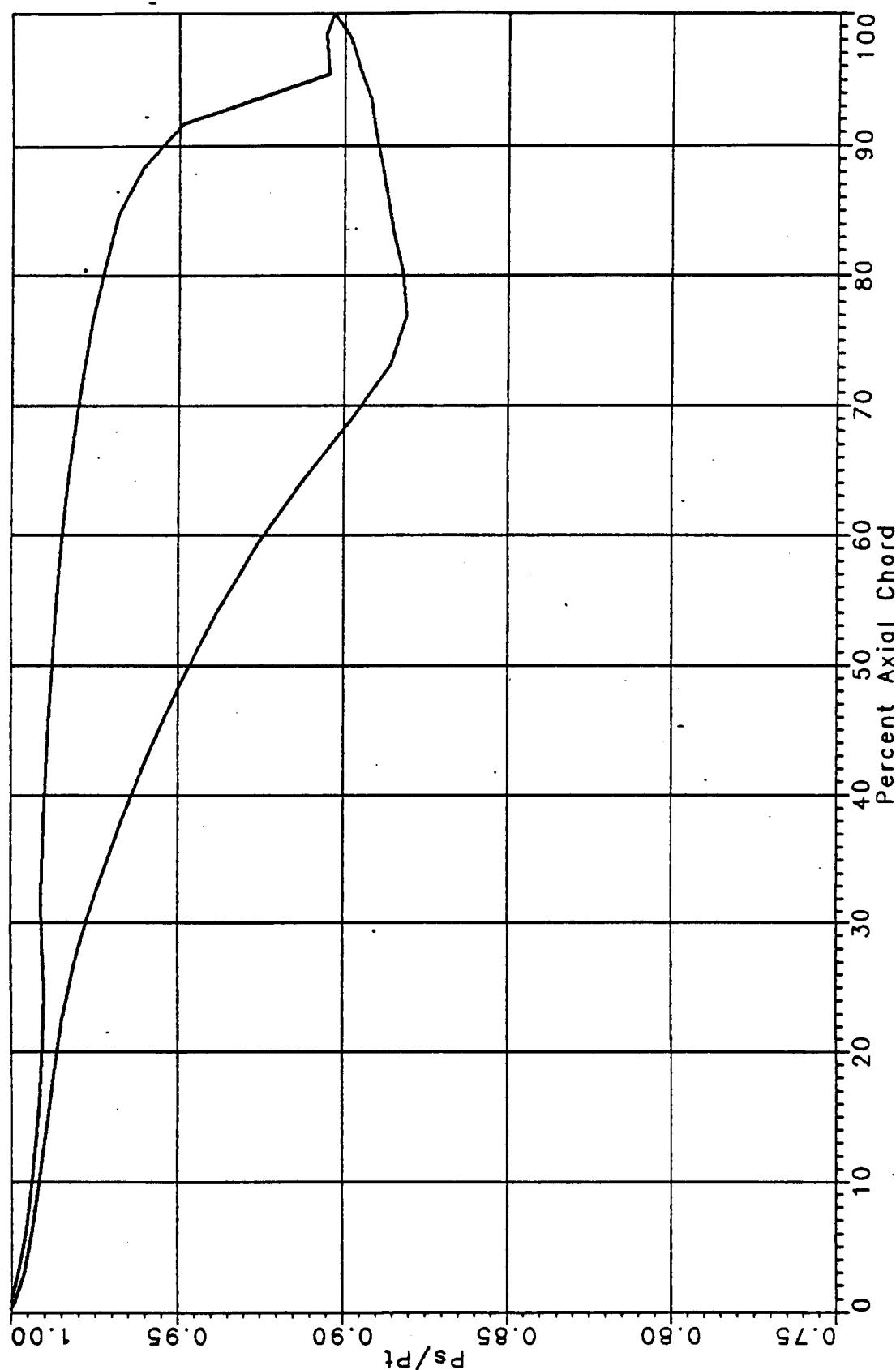
ATD LOX IV		OPERATING CONDITION		1		ADP					
NAE =	66.0	MCR =	0.0	MOM =	0.0	MHT =	-4.0	MXT =	0.0	MNT =	0.0
RPM =	0.	MYR =	0.0	MHM =	0.0	MHT =	-27.2	MNT =	0.0	NET BENDING	
/S	RADIUS	SIG P/A	SHRD P/A	LE	TE	CONV					
0	4.7000	0.	0.	1.	1.	-1.					
10	4.7615	0.	0.	-6904.	-1492.	6727.					
20	4.8229	0.	0.	-11598.	-2751.	11180.					
30	4.8844	0.	0.	-14671.	-3655.	14165.					
40	4.9458	0.	0.	-16357.	-4751.	15732.					
50	5.0073	0.	0.	-16673.	-5287.	15961.					
60	5.0688	0.	0.	-15676.	-5301.	14929.					
70	5.1302	0.	0.	-13499.	-4700.	12790.					
80	5.1917	0.	0.	-10196.	-3523.	9607.					
90	5.2531	0.	0.	-5723.	-1869.	5457.					
100	5.3146	0.	0.	1.	1.	-1.					
/S RADIUS XOFF YOFF 'Z'											
0	4.7000	0.0	0.0	1.	1.	-1.					
10	4.7615	0.0065	-0.0105	-6904.	-1492.	6727.					
20	4.8229	0.0119	-0.0188	-11598.	-2751.	11180.					
30	4.8844	0.0164	-0.0251	-14671.	-3655.	14165.					
40	4.9458	0.0204	-0.0295	-16357.	-4751.	15732.					
50	5.0073	0.0242	-0.0320	-16673.	-5287.	15961.					
60	5.0688	0.0278	-0.0325	-15676.	-5301.	14929.					
70	5.1302	0.0306	-0.0305	-13499.	-4700.	12790.					
80	5.1917	0.0324	-0.0260	-10196.	-3523.	9607.					
90	5.2531	0.0329	-0.0187	-5723.	-1869.	5457.					
100	5.3146	0.0327	-0.0102	1.	1.	-1.					
/S RADIUS AREA PULL LE TE CONV											
0	4.7000	0.0415	0.0	0.	0.	0.					
10	4.7615	0.0432	0.0	0.	0.	0.					
20	4.8229	0.0446	0.0	0.	0.	0.					
30	4.8844	0.0458	0.0	0.	0.	0.					
40	4.9458	0.0469	0.0	0.	0.	0.					
50	5.0073	0.0479	0.0	0.	0.	0.					
60	5.0688	0.0486	0.0	0.	0.	0.					
70	5.1302	0.0494	0.0	0.	0.	0.					
80	5.1917	0.0497	0.0	0.	0.	0.					
90	5.2531	0.0497	0.0	0.	0.	0.					
100	5.3146	0.0494	0.0	0.	0.	0.					
/S RADIUS MXT MHT MCG MTC THETA N											
0	4.7000	0.0	0.0	0.0	0.0	0.0					
10	4.7615	0.0	0.0	0.0	-1.4	-9.8	8.27				
20	4.8229	0.0	0.0	-2.5	-17.4	8.27					
30	4.8844	0.0	0.0	-3.3	-22.9	8.27					
40	4.9458	0.0	0.0	-3.8	-26.2	8.27					
50	5.0073	0.0	0.0	-4.0	-27.2	8.27					
60	5.0688	0.0	0.0	-3.8	-26.2	8.27					
70	5.1302	0.0	0.0	-3.3	-22.9	8.27					
80	5.1917	0.0	0.0	-2.5	-17.4	8.27					
90	5.2531	0.0	0.0	-1.4	-9.8	8.27					
100	5.3146	0.0	0.0	0.0	0.0	0.0	44.59				

ATD LOK 1V
 DENSITY = 0.31200 WEIGHTING RADIU INNER = 4.7000 OUTER = 5.3146
 SHROUD VOLUME = 0.0 SHROUD THICKNESS = 0.0
 SHROUD MISALIGNMENT = 0.0 RADIUS OF SHROUD = 0.0
 HEIGHT OF AIRFOIL = 0.00904 HEIGHT OF SHROUD = 0.0
 TOTAL WEIGHT = 0.74143 NUMBER OF BLADES = 62

SUMMARY OF SECTION PROPERTIES

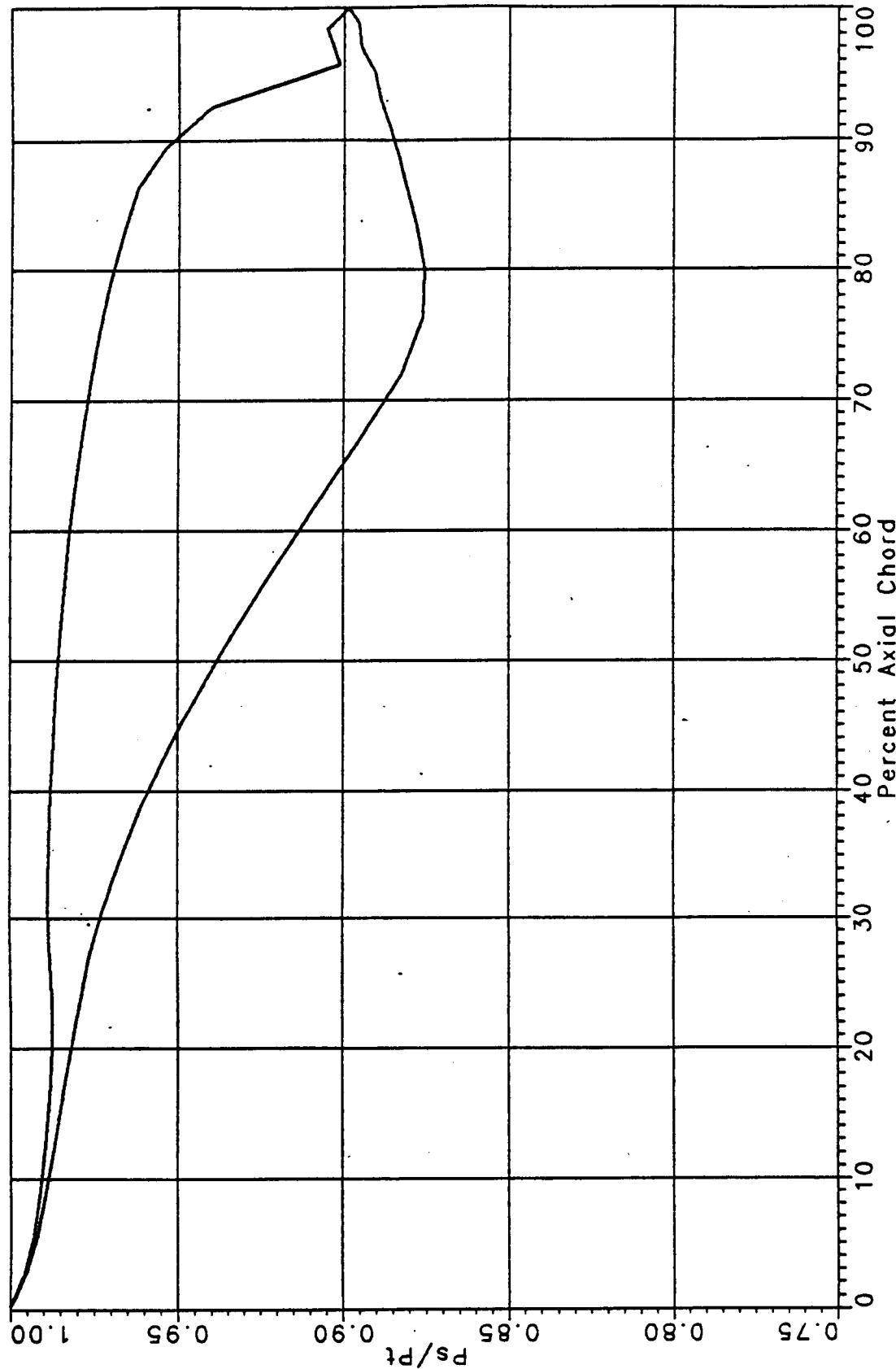
ZS	RADIUS	AREA	TMIN	TMAX	THETA	XBAR	YBAR
0	4.7000	0.0415	0.1423E-03	0.2579E-03	-40.66	-0.0000	0.0000
10	4.7615	0.0432	0.1344E-03	0.4448E-03	-41.09	0.0065	-0.0104
20	4.8229	0.0446	0.1517E-03	0.6772E-03	-41.58	0.0119	-0.0187
30	4.8844	0.0458	0.1608E-03	0.7338E-03	-42.05	0.0164	-0.0251
40	4.9458	0.0469	0.1668E-03	0.7694E-03	-42.47	0.0204	-0.0295
50	5.0073	0.0479	0.1717E-03	0.7845E-03	-42.80	0.0242	-0.0320
60	5.0688	0.0488	0.1742E-03	0.8979E-03	-42.97	0.0278	-0.0324
70	5.1302	0.0494	0.1790E-03	0.9382E-03	-42.90	0.0306	-0.0305
80	5.1917	0.0497	0.1792E-03	0.9591E-03	-42.55	0.0324	-0.0260
90	5.2531	0.0497	0.1772E-03	0.9577E-03	-41.93	0.0329	-0.0187
100	5.3146	0.0494	0.1747E-03	0.9445E-03	-41.19	0.0327	-0.0102
ZS	RADIUS	K	L	MAX T	AX WIDTH	C1	C2
0	4.7000	0.0	0.5533E-05	0.1441	0.3540	0.0941	0.0738
10	4.7615	0.0	0.7552E-05	0.1374	0.3604	0.0970	0.0793
20	4.8229	0.0	0.8656E-05	0.1327	0.3666	0.1007	0.0834
30	4.8844	0.0	0.9647E-05	0.1298	0.3726	0.1028	0.0865
40	4.9458	0.0	0.1111E-04	0.1285	0.3764	0.1042	0.0891
50	5.0073	0.0	0.1242E-04	0.1266	0.3843	0.1053	0.0914
60	5.0688	0.0	0.1368E-04	0.1309	0.3901	0.1060	0.0933
70	5.1302	0.0	0.1468E-04	0.1344	0.3959	0.1063	0.0942
80	5.1917	0.0	0.1525E-04	0.1394	0.4013	0.1059	0.0937
90	5.2531	0.0	0.1531E-04	0.1458	0.4065	0.1048	0.0917
100	5.3146	0.0	0.1514E-04	0.1528	0.4116	0.1036	0.0890
ZS	RADIUS	C3	C4F	CTE	C4	ALPHA_B	B
0	4.7000	0.1102	0.1471	0.2638	0.0361	51.97	0.4485
10	4.7615	0.1153	0.1531	0.2703	0.0447	51.28	0.4609
20	4.8229	0.1167	0.1585	0.2774	0.0385	50.64	0.4730
30	4.8844	0.1203	0.1634	0.2846	0.0420	50.03	0.4846
40	4.9458	0.1207	0.1682	0.2916	0.0436	49.48	0.4945
50	5.0073	0.1207	0.1730	0.2985	0.0443	48.99	0.5078
60	5.0688	0.1206	0.1775	0.3046	0.0442	48.66	0.5182
70	5.1302	0.1205	0.1812	0.3091	0.0425	48.62	0.5261
80	5.1917	0.1202	0.1834	0.3117	0.0366	48.94	0.5309
90	5.2531	0.1199	0.1840	0.3125	0.0443	49.62	0.5324
100	5.3146	0.1196	0.1837	0.3130	0.0393	50.45	0.5326

PRATT & WHITNEY
SSME ATD Oxidizer Pump Turbine
First Vane - 0% Span



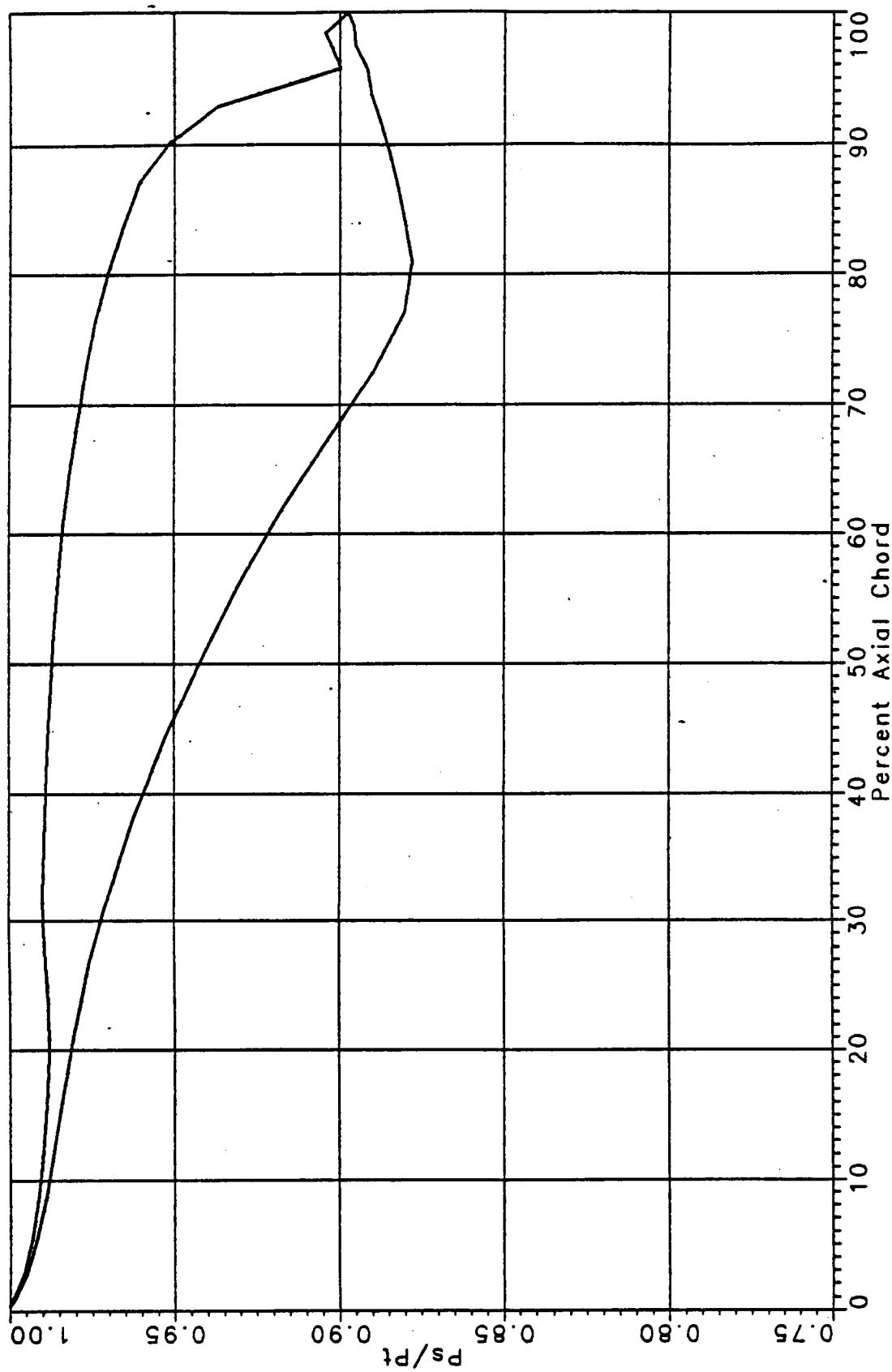
07/08/88
DL

PRATT & WHITNEY
SSME ATD Oxidizer Pump Turbine
First Vane - 25% Span



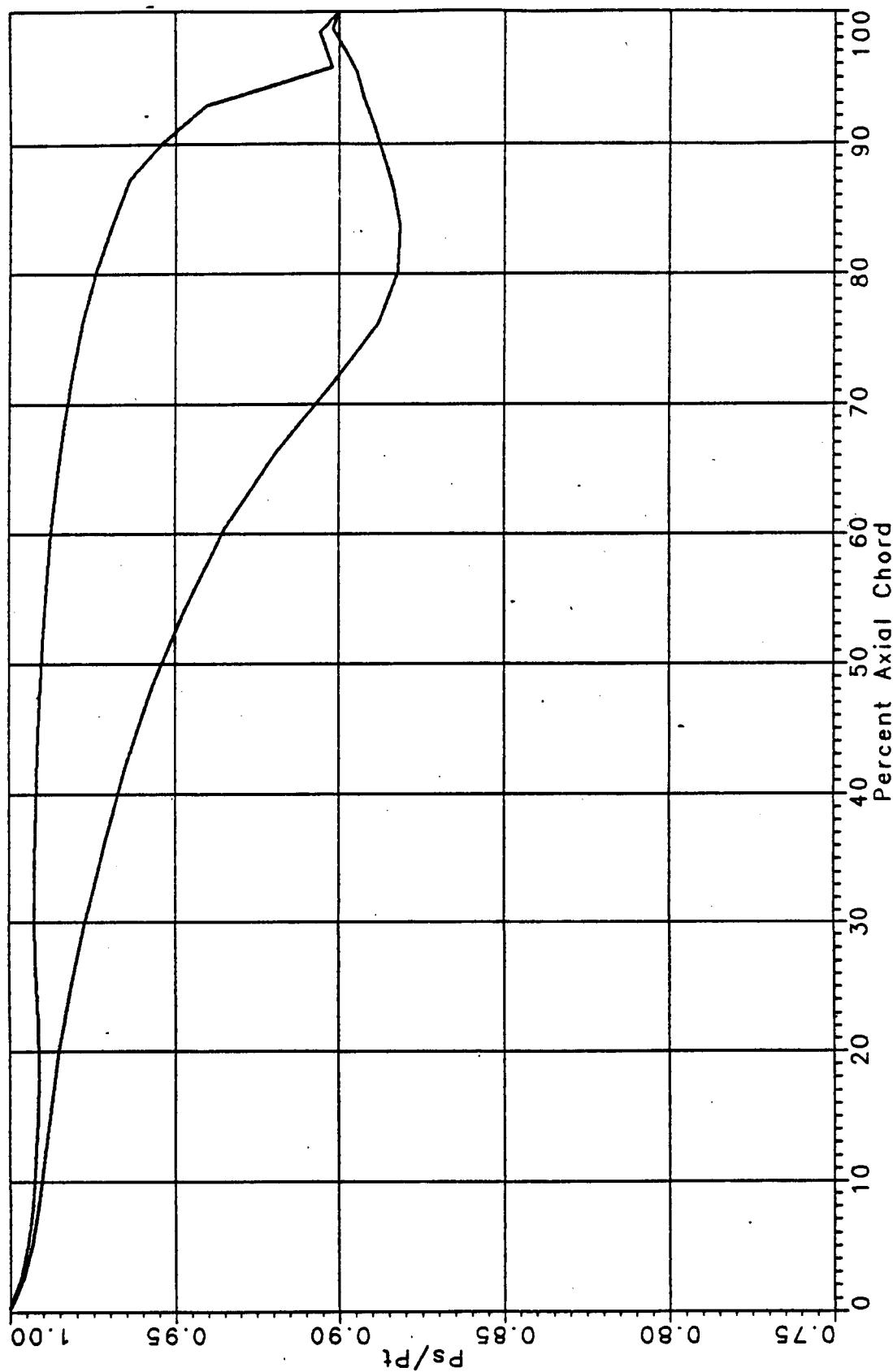
07/08/88
DLS

PRATT & WHITNEY
SSME ATD Oxidizer Pump Turbine
First Vane - 50% Span



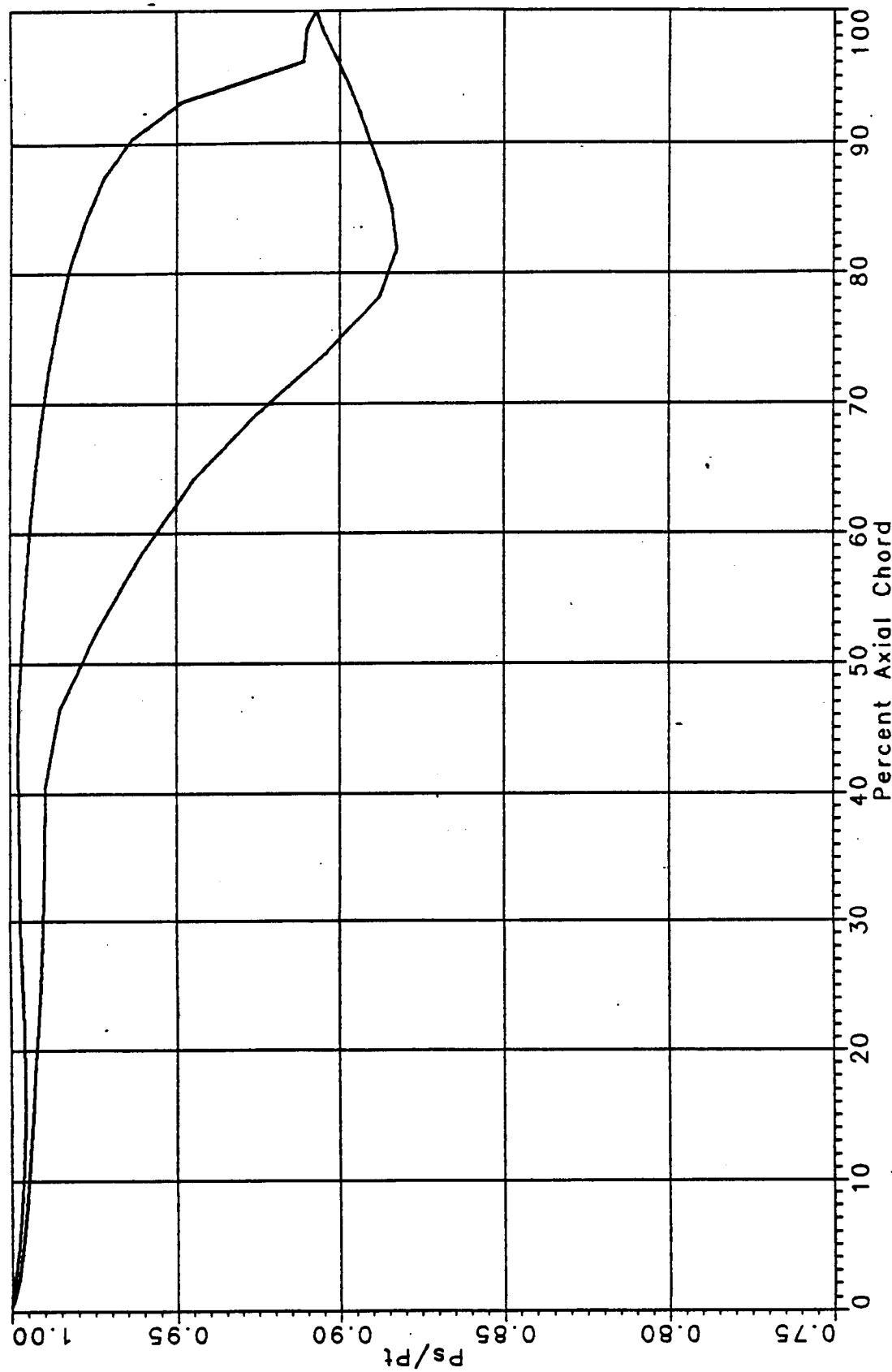
07/08/88
DLS

PRATT & WHITNEY
SSME ATD Oxidizer Pump Turbine
First Vane - 75% Span



07/08/88
DLS

PRATT & WHITNEY
SSME ATD Oxidizer Pump Turbine
First Vane - 100% Span



07/08/88
DL/S

U456 - FINITE TRANSITION INTEGRAL BOUNDARY LAYER DECK

DATE 01/20/88

TIME 14:21:18

SSME ATD Oxidizer Pump Turbine - 1st Vane - Mean Section

2.00% TURBINE

10.00% TURBINE

INLET MACH NO.

GAS ANGLES

EXIT

0.381

167.48

Suction Side

REF. REYNOLDS NO.

0.9100

0.9090

0.9080

0.9070

0.9060

0.9050

0.9040

0.9030

0.9020

0.9010

0.9000

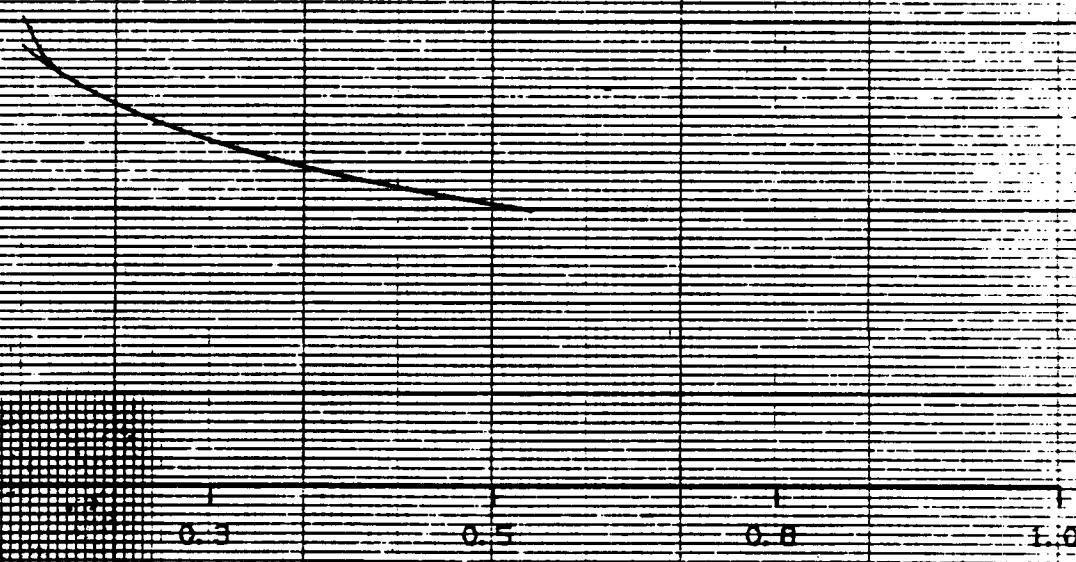
0.8990

0.8980

0.8970

0.8960

0.8950



S DISTANCE (INCHES)

TRANSITION CHART



S DISTANCE (INCHES)